THE

AËRONAUTICAL JOURNAL.

(Founded 1897 in succession to the Annual Reports).

The Organ of the Royal Aëronautical Society.

Published Monthly at the Offices of the Society, at 7, Albemarle Street, Piccadilly, London, W.1.
Telephone: "Gerrard 7373." Telegraphic Address: "Didaskalos, Piccy, London."
Subscriptions per annum, post free, £1 10s.; single numbers, 2s. 9d.

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All communications should be addressed to the Editor.

No. 100. APRIL, 1919. Vol. XXIII.

Notices of the Royal Aëronautical Society.

Elections.

The following have been elected to the membership of the Society in the various grades:—

Fellows.—Lieut.-Col. T. R. Cave-Browne-Cave, Major Linton Hope.

Associate Fellows.—Miss A. M. Trout, E. M. Rolfe, L. A. Martin, A. Landells, A. S. Goodwin, P. T. Carden, C. H. Waghorn, C. W. Tinson, H. A. Mettam, S. W. Luscher, W. E. James, A. W. Clegg, J. E. Appleyard, R. H. Mayo, J. J. Thompson, C. E. Waghorn, J. C. Bristowe.

Members.—W. H. S. Gee, J. M. May, T. Onishi, T. Tigura, Sir Walter Raleigh.

Student Members.—F. R. Coleshill, F. Duggins, E. T. Lawson Helme, F. A. M. Williams, K. S. Wise, C. S. Potts, C. Stuckey, R. Michaelis, T. W. Ballantyne, W. A. Wilkinson.

Associate Members.—R. L. Preston.

Foreign Members.—E. Gamble, E. C. Banks.

Committees of the Council.

At a Council meeting held on April 15th the following Committees were appointed:—

The Technical Terms Committee.

This Committee was reappointed *en bloc*.

Lectures and Publications Committee.

Major F. H. Bramwell.
Lieut.-Col. T. R. Cave-Browne-Cave.
Brig.-Gen. R. K. Bagnall Wild.
Mr. L. Bairstow.
Lieut.-Col. M. O'Gorman.
Major A. R. Low.
Mr. M. A. S. Riach.
Capt. A. P. Thurston.
Lieut.-Col. H. T. Tizard.
Mr. A. Ogilvie.
Mr. A. R. Rowledge.

Finance Committee.

Mr. H. White Smith. Mr. G. Holt Thomas.
Mr. A. Ogilvie. Mr. A. E. Turner.

Library Committee.

Lieut.-Col. T. O'B. Hubbard. Mr. F. Handley Page.
Sir Mackenzie Chalmers. Sir Walter Raleigh.
Dr. R. Mullineux Walmsley. Major A. R. Low.
Mrs. McAlister (*Hon. Librarian*).

Education Committee.

Dr. R. Mullineux Walmsley. Sir John Sykes.
Sir Robert Hadfield. Capt. A. P. Thurston.
Prof. Petavel. Major F. H. Bramwell.
Major A. R. Low. Prof. J. C. Lea.
Mr. A. E. Berriman.

With power to add to their number.

Obituary.

We greatly regret to announce the death of Mr. A. S. A. Ormsby, Associate Fellow, after a long illness. Mr. Ormsby took a leading part in the work of the Technical Terms Committee. He had been a member of the Society for many years and on every possible occasion rendered ungrudging service to the furtherance of aeronautical science. His wide knowledge and charming personality will be greatly missed.

Joint Committee with the Royal Meteorological Society.

This Committee has been reconstituted and the representatives appointed are as follows:—

Royal Aëronautical Society.	*Royal Meteorological Society.*
Major G. I. Taylor, F.R.S.	Sir W. Napier Shaw, F.R.S.
Dr. T. E. Stanton, F.R.S.	Col. Gold, F.R.S.
Col. W. Briggs.	Capt. C. J. P. Cave, R.E.
Mr. A. Ogilvie, C.B.E.	Capt. G. M. P. Dobson.

The Wilbur Wright Lecture this year will be given by Mr. Leonard Bairstow, at the Royal Society of Arts, on June 18th, at 8.0. His subject will be "Progress in Aviation during the War Period. Some Items of Scientific and Technical Interest."

In celebration of its 50 years of existence and the fact that it has now exceeded 1,000 members, the Society will hold a Garden Party at the Cricklewood Aerodrome (by kind permission of Mr. Handley Page), on Sunday, June 29th, between 4.0 p.m. and 7.0.

THE RIGGING OF AEROPLANES.

BY CAPTAIN R. J. GOODMAN CROUCH, R.A.F.

Introduction.

The rigging of aeroplanes, although not a subject necessitating extensive research work or particular scientific knowledge, is of paramount importance, in view of its effect on the safety, reliability, and performance of machines.

The mechanical principles involved are well known to the engineer, and their application rests to a great extent on experience.

In a word, practicability governs both construction and erection.

It is obvious that the slightest error in erection, or lack of care in inspection, may lead to the most serious consequences, resulting in loss of life or grave injuries and considerable material damage.

It is therefore essential in any establishment where rigging and erection are undertaken as routine work that systematic methods should be employed, operations standardised where possible, and elaborate means allowed for the necessary checking and re-checking of the work.

In every organ[illegible]tion system is the keynote of efficiency, and aviation is certainly no exception to the rule.

Standardisation of operations has been rendered possible by the adoption of particular methods of construction and the use of jigs both for detail work and assembly, while reliable checking can be ensured by the definite fixing of responsibility.

As progress is made and newer and larger types of machine are designed it will become increasingly difficult and finally impossible for anything more than a rough superficial examination and a test of controls to be carried out on any aeroplane prior to a flight.

At present it is a simple matter in small machines to check over bracing wires, to see that all fittings are locked, and to test the controls as a final precautionary measure; but in the case of larger machines, of the "bomber" class, a daily routine examination is necessary for controls and bracing, while a weekly inspection of the planes, interior of fuselage, etc., is advisable at any station or aerodrome where machines are in constant use.

It is highly important, therefore, that methods which will ensure as far as possible correct rigging during the erection of the machine should become general in order to obviate the possibility of errors being made through lack of experience or other causes.

As far as the Royal Air Force is concerned, the publication of Rigging Notes and Diagrams has been of great value to Repair Depôts and Air Stations.

These notes, in the form of a small pamphlet for each type of machine, describe the methods to be used in truing up and erecting, while large sheets showing diagrammatically the manner of checking and adjusting all wires have been distributed for use in erecting sheds. Examples of these rigging diagrams are seen in Figures 1, 2 and 3.

Descriptive handbooks with illustrations have also been compiled, from which a good idea of the distinctive features of the various types may be obtained.

In the future, when flight becomes a more regular form of transport, great attention will be paid not only to the best means of erecting new machines, but

also to the facility with which repairs, readjustments, and re-erection can be carried out far from the original factory or aerodrome.

Experience gained on active service air stations has proved of great value in this respect, for the conditions under which machines were repaired and rigged showed the necessity of having standard parts easily detachable and readily reassembled.

A striking example of this was found in a small Tractor Scout, in which, for production reasons, the engine bearer plate was furnished with sockets to receive the forward tubular struts of the undercarriage, the engine bearer and the sockets being made of the same piece of metal. Thus whenever a bad landing occurred, which caused the slightest deformation of the chassis sockets, it became necessary to dismantle the engine and renew the engine bearer plate before a fresh undercarriage could be fitted.

This disadvantage was remedied by a slight modification in design, by which the sockets were made easily detachable from the bearer by the removal of a few small bolts.

Such points are worthy of careful consideration in design work, in order that machines may be out of action for the least possible time when some slight damage is incurred.

Moreover, arrangements will doubtless be made to enable machines when undertaking journeys to distant parts to carry, as part of their normal equipment, those spares which are most likely to be required.

Aircraft depôts, at which thorough overhaul can be undertaken, will undoubtedly be organised at the various junctions of the world's main airways, for the working life of an aeroplane is a factor which must not be overlooked. After 40 or 50 hours in the air the fabric usually becomes " soggy " and requires replacing, while 100 hours would appear to be about the maximum flying time of a large machine before requiring thorough overhaul.

Small machines of high performance are not capable of such a long period, and as a general rule a visit to the shops is necessary after about 50 hours in the air, including, say, 30 to 40 landings.

It is extremely difficult, however, to say how many times a machine can be overhauled before deletion. There would appear to be no actual limit provided that all fatigued parts are renewed when the machine is repaired, but under these circumstances it is obvious that after a few visits to the repair shops very little, if any, of the original machine would be left.

Inspection and Precautions.

The choice of materials used in aircraft construction is a question of great interest to the designer, for perhaps in no other branch of engineering as in aeronautics do the distinctive qualities of the various metals and woods employed assume such a degree of importance. Strength with lightness is the governing factor.

The selection and inspection of particular materials occupies, too, a prominent place in aircraft production, while the thorough examination of all parts to be fitted to a machine from the largest strut to the smallest split-pin is of vital importance during construction and rigging.

Rust especially should be stringently guarded against, for a rusty lug may mean catastrophe, and it is highly important that all metal fittings, wires, bolts, etc., should undergo the closest scrutiny before being used.

As a general rule, for metal work, light paint is advisable as a protective measure, while for separate machined parts zinc-electroplating has been found to be an efficient anti-corrosion process.

Steel tubes, when kept in store, should be well oiled on the inside and fitted with plugs at the ends, and bent tubes should on no account be used.

Wires and cables require very careful examination, for the fracture of a wire in the air is a serious matter.

Streamlined wires are used on machines designed for a high performance wherever external bracing is essential. Small spanners should invariably be employed at short intervals along the wire in order to avoid " kinks " and bends.

All flight, landing, and incidence wires, as well as centre section, undercarriage, and tail unit bracing wires are of streamlined section, and in many cases, in view of ease of production compared with swaged rods, it is used for internal bracing, although from other points of view the latter is preferable for wiring not exposed to the air flow.

The decrease in head resistance owing to replacing unfaired cables or piano wires by streamlined wires is considerable, and a comparison of various aeroplanes shows a difference on top speed of approximately 2½ per cent. on small and about 6½ per cent. on large machines.

This decrease in resistance is its *raison d'être,* but a further advantage is found in erection when dealing with wires of definite length for various parts of the machine, although this necessitates a number of spare wires being kept at rigging centres. The demerit, however, is lessened considerably when one type of machine is produced in large numbers.

The increased performance, the ease of fitting, and production advantages obtained by its use easily outweigh the slight inconvenience entailed, and its use is now standard on both land and sea machines, except in the case of a few large boat seaplanes where performance is of secondary importance and where vibration is considerable; in this case cable is preferable.

The question of locking streamlined wires has resulted in several " gadgets," the neatest perhaps being the " locking plate." (See Fig. 4.)

For the main controls stranded cable of the extra flex type should always be used, care being taken to see that it is regularly twisted and not frayed at the ends.

It has now become a regular practice at repair depôts to employ control parties, who deal exclusively with the examination and upkeep of the controls of all machines as they come into the shops. These men, who are expert splicers, inspect and renew cable where necessary while other machine repairs are under way.

Before making up the ends cable should be thoroughly stretched in order to straighten it out after being coiled, and after the end splices are made each piece should be stretched again to 10 per cent. in excess of its normal flying load.

Pulleys should have a diameter from groove to groove of about 20 times that of the cable, but this point should be governed by the tension required.

Fairleads and flexible tubes are efficient for obtuse angles.

Bolts and nuts should be carefully machined all over, giving a good fit without slackness, the threads being clean and not worn or burred.

Castellated nuts for locking are extremely useful in cases where bolts may be subsequently removed, but in the case of a permanent fixture the end of the bolt should be riveted over.

Strainers or turnbuckles give scope to numerous inventors, but probably the most efficient form is that in which the thread is of such a length as will ensure a good factor of safety, the remainder of the shank being machined. By this means checking is greatly facilitated, for safety is assured when the thread has disappeared from view.

Soft iron wire should be used for locking, sticky tape as a covering being

deprecated. There is amongst riggers a temptation to use sticky tape not only on strainers and ferrules, but also on wires where they cross. This is not a good practice, as rust or defects may be concealed.

Waxed cord has been found to be quite efficient in obviating chafing.

When repairs are carried out on wood members the correct wood should always be employed, properly seasoned, and without signs of flaws, etc. It should be given a coat of shellac before assembling, while a second coat of varnish after the parts are glued, but before they are covered with fabric, forms ample protection.

Fabric should be attached to the main planes by sewing to the ribs, and this operation should be undertaken carefully, as cases have occurred where control wires running through the planes have actually been " sewn in " when stitching. Stitches should be about 3in. apart and waxed string used to prevent slacking off. This should be knotted after each stitch and double knotted every 18in. so that the fabric will not come adrift should the string break. Glue should only be used for fabric when it is required to strengthen solid members, as in the case of tape on spars and ribs, and a covering of dope may be given.

In no other case should glue be used for fastening fabric, as, apart from the fact that the latter is liable to rot, the hardened glue forms a sharp edge capable of cutting through the fabric at the slightest vibration.

With regard to fuselage covering, lacing is employed on many types, in order to facilitate stripping for the inspection of controls, internal bracing, etc. Here also knots should be made at intervals so that should the lacing break at any point the fabric is not blown loose.

Connection between doped fabric and bare metal should at all times be avoided.

Double rows of stitches and " balloon " seams should be made when joining fabric, but when patches are required the edges should be frayed.

The question of doping is dealt with in the various approved schemes of the Inspection Directorate, and need not be considered fully here. Mention might be made, however, of the danger of " thinning down " dopes and varnishes and the necessity of a constant temperature being maintained during the application and drying of the dope.

Dope poisoning by inhaling the gases given off can be prevented by strict attention to ventilation, forced draughts, etc.

Rigging.

Reference has already been made to standardisation, and much time can be saved in erecting when standard material and interchangeable parts are used.

It has been the practice, in order to economise labour, for specifications to be issued governing qualities of materials and tolerances of parts used in machines destined for the Service, while schedules of Air Board or A.G.S. standard fittings have been distributed to firms interested.

The first steps towards standardisation in construction have thus been taken, and as time goes on erection will probably be carried out by a series of mechanical operations.

At present " jigs " are becoming more and more general, but after assembly " truing up " is carried out by hand.

The necessary equipment is simple in the extreme. Spirit-levels, straight edges, plumb-lines, etc., require no explanation.

The Inclinometer or Abney Level is used for measuring incidence, and

consists of a hinged spirit-level furnished with a Vernier scale, on which the angle taken up by the base of the instrument can be accurately read.

The trammel consists in a simple form of a baton fitted with two movable points, and is of great use in comparing distances between marked centres for bracing purposes.

The use of the tautness meter is not at present general as far as aeroplanes are concerned, for experienced riggers are able to judge by hand when a wire is at the correct tension. Moreover, the instrument is primarily designed for use with cables which, as already stated, are not used on high-performance machines. Several forms of this instrument have been invented, and in one, designed by Colonel O'Gorman when Superintendent of the Royal Aircraft Establishment, the wire was bent to a definite angle and its resistance measured against that of a spring, the tension on the wire being registered on a dial.

Although rigging and erecting methods may be slightly varied according to circumstances, the order of erection and the way in which the various components are trued up by the manufacturers give a clear idea of the procedure in vogue.

The staff employed is, of course, dependent on the output required, and specialised workers are employed, while at erecting centres dealing with many different types men of more general knowledge are necessary.

In the latter case, however, it is highly desirable that the *modus operandi* should be closely allied to that of the manufacturer.

The usual methods employed in rigging may best be described by considering two or three representative machines. A Single-Seater Scout, a Two-Seater Ship Aeroplane, and a Heavy Bomber or Load Carrier suggest themselves as types.

SINGLE-SEATER SINGLE-ENGINED TRACTOR.

The particular aeroplane proposed for this type is the Sopwith Biplane F.1, fitted with 130-h.p. Clerget engine, better known as the "Camel." This machine has a span of 28ft., an overall length of approximately 18ft. 9in., and a height of 8ft. 6in. The weight empty without petrol, oil, guns, crew, etc., is 930lbs., while the total weight fully loaded is approximately 1,450lbs. (See Fig. 5.)

Fuselage.

The skeleton fuselage is composed of four spruce longerons connected by vertical and transverse struts, and is assembled on a "jig," which ensures the appropriate slope being given to the longerons and the correct positions to the vertical and transverse struts. The entire fuselage is supported on two trestles, one being placed under the first and the other under the last bay. Marks are made on each of the vertical side struts at given distances below the upper edges of the top longerons; these points lie along the thrust line in side elevation when the machine is trued.

Between the first and fourth side struts the upper longerons are parallel to the thrust line, while from the fourth strut to the tail they gradually slope downwards. A straight edge is lightly clamped transversely across the third strut so that the marked points are level with its upper edge.

Small blocks of wood are next clamped at all the other marked points so that their upper edges are coincident with these points. (See Fig. 6.)

Truing up is then commenced by adjusting the internal cross-bracing wires until the diagonals are equal in each section. This should be checked by the trammel. The top cross-bracing wires should be adjusted until the diagonals in each bay are equal, the bottom cross-bracing wires being similarly treated.

The next stage is to place suitable packing blocks under the forward supports until a spirit-level shows the transverse straight edge to be horizontal. This same process is repeated along first one side of the fuselage and then the other until consecutive blocks are horizontal while the side struts are vertical, adjustment being made by the side cross-bracing wires. A plumb-line will show when the side struts are vertical, while the stern post will be so if the truing up to this stage has been correctly performed.

The tail skid is then fitted. It is furnished with strong Sandow elastic, so that when the machine lands and the tail comes to earth the shock is absorbed, thus saving the fuselage from strain or fracture. The top longerons in the pilot's cockpit are then reinforced to make up for absence of bracing.

Instruments, fairing, and deck present no difficulties in fitting, but a word concerning the principal instruments may not be out of place.

The compass should be placed so that it is easily visible from the pilot's seat, and should be situated in the vertical plane through the fore and aft centre line of the machine. Its actual position is, of course, governed by the engine, magneto, etc., from which it should be placed as far as possible.

The cross-level should be directly in front of the pilot, while the air-speed indicator dial should be in close proximity to both compass and cross-level.

These three highly-important instruments are thus brought into a small zone of vision from the pilot's position.

Oil and petrol pressure gauges, altimeter, " rev." counter, aero-thermometer, watch, and petrol capacity gauge are placed in convenient positions.

The pressure gauges should be checked against a standard instrument before fitting, and pitot tubes should be carried well out of the slip-stream of the propeller or of any body whose interference would affect the air flow. A convenient position is the leading edge of the top plane. The pilot's control column, or " joy stick," and rudder bar are fitted to a transverse member on two longitudinal supports attached to side struts.

Undercarriage.

The undercarriage comprises a forward and a rear streamline strut on each side arranged in V-shape, while the axle is in two parts, pivoted at the middle and suitably faired. After fitting, the complete undercarriage is trued up by the adjustment of diagonal bracing wires.

A vertical streamline wire attached by a bolt to the mid-point of the axle-fairing prevents deformation when landing.

Preliminary Erection.

Before the wheels are mounted the machine is placed in flying position.

The undercarriage is supported on blocks and a trestle placed under the tail. The skeleton machine can then be levelled longitudinally by raising or lowering the tail as required and transversely by packing blocks under the chassis struts.

When the forward spar at the bottom of the fuselage is horizontal transversely and the top longerons from the nose to the pilot's bay are horizontal longitudinally the correct position is obtained.

The skeleton centre section, main planes, and tail unit are then rigged and trued up and the controls loosely connected. (See Fig. 7.)

Centre Section.

The centre section is symmetrical about the vertical line of the machine. The forward struts are furnished with four wires running from the upper and

lower extremities to a ring attachment in the centre. A fair resultant is thus obtained for each wire, and this arrangement has the additional advantage of permitting the fixture of two synchronised Vickers' guns on the top of the fuselage without fouling the wires. Adjustment is made until corresponding wires are equal in length. (See Fig. 8.)

Main Planes.

The lower main planes are attached to the fuselage by fittings at the root of the main spars, a securing rod being inserted at each side from the rear and split-pins used for locking purposes. The landing wires are then loosely connected, after which the upper main planes are lifted in position, the securing rods in this case being inserted from the front and secured to the leading edges of the main planes. Flying and incidence wires are fitted into position, but allowed to remain loose.

The next step is to true up the main planes. Plumb-lines are dropped from four points on the leading edge of the upper planes and the various wires adjusted until the following conditions are fulfilled :—

(*a*) Plumb-lines are in line, viewed from the side.

(*b*) The leading edges of the upper main planes are in line in both front and plan view, there being no dihedral angle on the upper planes.

(*c*) The leading edge of the lower plane is symmetrical about the centre line of the machine. This can be checked by taking measurements from the bottom sockets of the forward outer struts to the rudder post and to the propeller boss.

(*d*) The correct dihedral of the lower planes is obtained by placing straight edges along the front and rear spars and reading the angle on an inclinometer or Abney level.

(*e*) The stagger is the same throughout, which again is checked by measuring the fore and aft distance from the leading edge of the lower planes to plumb-lines dropped from the leading edge of the upper planes and centre section.

(*f*) The incidence angle is fixed by adjusting incidence wires, and is checked by placing straight edges underneath wing ribs from the leading to the trailing edges. The inclinometer records measurement of the angle.

(*g*) There is no " wash in " or " wash out."

Tail Unit.

The tail plane is bolted into position and the bracing wires connected up and adjusted until spirit-levels show the front spar and hinged tube to be horizontal.

Care should be taken to see that the tail plane is square with the machine. Measurements taken from the outer interplane struts to the tail plane spars form a good check.

Owing to the camber on the upper and lower surfaces of the tail plane the incidence can best be measured by a straight edge furnished with two small wooden blocks. These are of such dimensions that when one is on the front spar and the other on the hinged tube the straight edge is parallel to the fore and aft centre line of the tail. An Abney level gives the angle of incidence.

The fin is bolted on and the rudder hinged to the fin and the stern post, split-pins being used for locking. Similarly the elevators should be hinged to the rear spar of the tail plane. These are rigidly connected, so that if the control is damaged on one side they may be operated from the other.

The controls should then be loosely connected as a check before dismantling main planes, centre section, and tail unit. (See Fig. 9.)

Power Plant, etc.

Petrol tanks and various cockpit accessories are now fitted, after which the fuselage is covered and doped. The engine, complete with accessories and controls, is mounted, and in a machine required for war purposes the gun magazines and chutes are placed in position; oil tanks, gun or guns, and actuating gear follow.

Meanwhile the fabric and dope experts are busy on the centre section, main planes, and tail.

Final Erection.

The centre section is the first of these to be required, and as soon as re-erected the wheels and shock absorbers can be mounted. Then the engine cowling is fitted and main planes and tail unit re-erected. The final operation is the adjustment of controls. These should be adjusted so that when the "joy stick" is central the trailing edges of the ailerons are in line with the trailing edges of the planes. The position of the elevators is fixed by adjusting the wires until some specified point on the "joy stick" is at a given distance from a known point in the pilot's cockpit when the elevators are neutral.

The rudder and tail skid are in the fore and aft line of the machine when the rudder bar is square in the fuselage. This completes the rigging of the machine.

A test flight shows whether any minor adjustments are necessary.

TWO-SEATER SHIP AEROPLANE.

This type of machine, used for wireless reconnaissance and spotting work with the Grand Fleet, is necessarily governed by service requirements.

It must be capable of easy and safe stowage in limited accommodation, able to fly from deck platforms with a very short run, and to land either on the deck or water. Ample controllability at slow speeds is necessary for deck landing; while for the water means to prevent overturning and devices enabling the machine to keep afloat in a suitable attitude, must be provided.

The Parnall "Panther," fitted with 230 h.p. B.R.2 engine, forms an excellent example of this class. (See Fig. 10.)

In order to meet the conditions of stowage and turret flying the span has been kept as small as possible, while the fuselage has been made to hinge just behind the observer's cockpit. The advantages claimed for this arrangement are:—

(*a*) Lightness.
(*b*) Truth maintained in wings.
(*c*) Folding can be carried out after removing two pins only.

A good field of view is obtained by placing the pilot as high as possible, while the planes which have a deep chord are staggered.

The large range of speed (from 42 to 105 knots) permits of quick manœuvrability and easy landing. A hydrovane fitted to the chassis provides against somersaulting when coming on to the water, and air bags form suitable flotation gear.

Fuselage.

The fuselage is of ply-wood monocoque type and is very deep at the forward end, the pilot and observer being high up and protected by a kind of hump

superposed on the elliptical body. This particular shape renders the downward view as good as possible for reconnaissance purposes.

In the usual rotary engine machine, in which the rudder bar is situated below the carburetter, and where the cooling air is emitted beneath the fuselage, good downward view is obtained with difficulty. If, however, the fuselage is made elliptical the air being emitted from each side, and the pilot is placed relatively high up with his rudder bar above the carburetter, his downward view is immensely improved. Full advantage has been taken of these facts in the present case.

The fuselage is constructed in two distinct parts, which are afterwards hinged together. These are assembled on jigs which give the correct height and spacing to the rings or bulkheads. (See Fig. 11.) It is of interest to note that the design of these rings permits alternate sizes to be cut from the same sheet.

Four main longerons run the whole length of the machine, while in the rear portion light stringers are placed between them to give good rigidity.

Birch plywood 1/16th inch in thickness is glued and screwed on in sheets to form the skin. This is afterwards covered with fabric which is glued on and doped. Numerous advantages are claimed for this method of construction. Few steel or welded fittings are required, thus minimising weight and labour; while, at the same time, great strength is obtained. A three-ply channel suitably lightened runs down on the inside of the fuselage at the starboard side. The tail control wires are led through this channel which protects the air bag from friction. Several holes are pierced on the underside of the fuselage so that any water which may enter soon disappears.

Towards the tail end steel tubes are fitted horizontally through the fuselage with T-piece handles on the outside. These facilitate lifting and folding.

The tail skid is made of ash with duralumin side-plates and is attached to a specially strengthened bulkhead. Ordinary shock absorbing elastic is used, but the skid is somewhat notable for a ball fitting provided at the tip instead of the usual plough or protection plate. When carried on the deck the skid is supported in a slotted tube which keeps the main planes at a small angle until sufficient air-speed has been acquired. Swivelling is prevented by means of a slotted plate in the fuselage. A removable plywood panel gives good accessibility for inspection and adjustment.

The front portion of the fuselage is occupied by the pilot's and observer's cockpits, and is of somewhat more solid construction than the rear. The bulkhead between the two cockpits is of particular interest and forms the support for the wireless apparatus. The rear flying wires are attached to a single fitting at the centre of the lower cross member in this bulkhead, and extension links are provided in order to bring the adjustment above the floor. Lift loads are taken by upward diagonal struts from this point, these struts being stabilised by the wireless frame. The bottom cross member takes the squeezing tendency on landing, and also serves to support the rear end of the main petrol tank. The W-shaped sling at the top of the bulkhead is employed to support the rear end of the seat and control bearers by means of eyebolts. The fittings for attachment of the rear undercarriage struts and the top centre section struts are located at the points where the main longerons run through the bulkhead.

The control unit is assembled complete before fixing in the fuselage. When in position the bearers for the seat and controls rest with their forward ends on the rear engine bearer, to which they are bolted, while the rear ends are suspended from eyebolts as already stated.

Fore and aft motion of the "joy stick" is transmitted by a tube running aft to a transverse shaft running in journals on the seat bearers. A lever pinned to this shaft, on the starboard side, takes the elevator control cables.

Motion is transmitted from the rudder bar by cables to a lever underneath and to the rear of the pilot's seat; while on the same spindle is another lever fixed at right angles to it. The rudder control cables run from this second lever to the starboard side of the machine where they pass over pulleys.

Both elevator and rudder cables are thus brought to one side of the rear cockpit out of the way, and from this point they pass outside the folding hinge of the fuselage and over a distributing nest of pulleys located in the rear section of the fuselage. Lateral movement of the "joy stick" is transmitted through a longitudinal shaft to a transverse lever from which cables are led round pulleys and along the leading edges of the lower planes to the ailerons.

To the foremost bulkhead is attached the rear engine bearer, while the main plate of the engine is carried on outriggers. By this means the whole engine complete with magnetos, pumps, etc., can be assembled and fitted as a whole. The same advantages hold good for dismantling.

Various fittings for the pilot's cockpit are then mounted, and the observer's bay furnished with a hinged seat and, in the case of military machines, a Lewis gun mounting.

A covering of three-ply and fabric, as in the case of the rear portion, completes the section, and the two sections are joined.

The fuselage is now complete. The various components of the fuselage having been trued up on "jigs" during erection, should maintain their correct relative position. Should, however, deformation or fracture be incurred by subsequent accident no re-truing is possible. An entirely new fuselage is the only way out of the difficulty.

Undercarriage.

The undercarriage forms another complete unit. It is composed of streamline struts connected by a bottom horizontal member forming a broad U, in contrast to the usual V-type. This particular shape permits of the Sandow elastic shock absorber being placed in line with the struts, and this in turn allows the wheels to be brought up closer to the struts than is ordinarily the case. Incidentally a bent axle can be removed without disturbing the shock absorbers.

Here it may not be out of place to mention the emergency landing gear, which consists of a wheel release device, hydrovane, and air bags. (See Fig. 12.)

The hydrovane is fitted to the front of the undercarriage well in front of the centre of gravity. The plane itself is of spruce reinforced with sheet steel, and is attached to the fuselage by struts whose top fittings grip the forward undercarriage main attachments. To withstand the longitudinal strain when landing steel tubes are carried back to the undercarriage. The complete hydrovane with its struts and attachments forms a separate unit which is readily assembled and dismantled.

Three main air bags are provided, one on either side of the chassis and one in the rear section of the fuselage.

The two main bags under the planes are folded up to form a long roll on each side. The rolls are retained in position by covering flaps, which can be released at will by cables. Air is admitted to the bags by an air-bottle charged to about 1,800 lbs. per square inch, additional air being sucked in through an injector. After charging the bags the air is retained by closing a cock in the system. The back bag in the fuselage is maintained as fully inflated as possible. In the ordinary course of flying it is kept open to the atmosphere, so that differences of pressure due to change of altitude do not strain the fabric.

When it is desired to employ the landing device the entrance is closed and the bag becomes sealed.

The air bags are operated by a pneumatic release so that landing becomes as simple as possible, and the following two actions only are necessary:—

1. Open air valve.
2. Close main cock when bags are full.

Each wheel is held in position by a pin with an elastic safety contrivance preventing its inopportune discharge. When release is required these pins are withdrawn by cables running to the pilot's cockpit, and spiral springs inside the axle tubes throw the wheels clear.

In order to fit the undercarriage the machine is suspended by means of cables attached to special lugs at the first and fourth bulkheads.

Should, however, slinging gear not be available the machine must be chocked up with a trestle under the tail and a steadying shore under the propeller boss.

The forward struts of the undercarriage are attached to the front bulkhead. The upper ends of the rear struts then come automatically into position for fixing.

The machine is then lowered to the ground and the engine and its accessories fitted, before rigging the main planes.

Centre Section and Main Planes.

The most notable features of the main planes are:—

(*a*) The fact that the ailerons are enclosed in the wing and not carried out to the tip, as is usual.
(*b*) That the wing tips are replaceable.
(*c*) That the middle portion of the top centre section is cut away.

The peculiar position of the ailerons has the dual advantage of eliminating twisting effect and minimising hand control.

Twisting effect is obviated by disposing the aileron almost symmetrically about its operating lever. Hand control is kept small by designing the ailerons so that their chord is small compared with the chord of the planes. It is obvious that were the ailerons to extend to the ends of the wings this proportion would be changed owing to the shape of the wing tips.

The advantage of replaceable wing tips is apparent for a machine which is hoisted on board ship. They are made detachable just outside the ailerons and are, of course, interchangeable.

The hole cut away in the top centre section allows the pilot to enter his seat with ease. A hinged flap at the rear of the spar is a further convenience; while, as a means of speedy exit, the arrangement is ideal when the use of the machine is considered.

It is worthy of note that owing to the peculiar construction employed no "datum line" exists in the fuselage. Flying position, however, is obtained when the front bulkhead behind the engine is vertical and cross struts in the bulkhead horizontal.

The centre section with two gravity tanks, fitted internally, one on either side of the central hole, is then rigged.

The struts are first placed in position on the fuselage and the centre section itself bolted on.

By adjusting the athwartships cross-bracing wires until they are the same length the top main spar will be level.

The centre of the front main spar should then be over the centre of the cross struts in the fuselage. The correct stagger and incidence are given by the appropriate wires.

The lower main planes are next erected, the wing roots being attached to

central spars running through the fuselage. The correct incidence is ensured by the fact that the spars in the fuselage are "jig drilled."

The wing tips should be shored up to take the weight off the fuselage as the latter might easily be brought out of flying position were this precaution not taken.

The landing wires running between the lower extremities of the interplane struts and the upper ends of the centre section struts are then loosely connected.

The interplane struts should be all ready and the flying wires attached to the fuselage beforehand. Two men should occupy the pilot's and observer's seats and another man should be on a step-ladder at the wing tip. The top plane is then lifted into position, the struts are fixed into their sockets, and the flying wires joined up.

Truing up is then carried out in a similar manner to that employed in the case of the "Camel." With the present machine, however, a dihedral angle is given to both upper and lower planes, while the incidence is measured between the spars.

In order to counteract propeller torque a slight "wash-in" is given on the port side and a "wash-out" on the starboard side.

The connecting up of the aileron control wires is a simple matter, as the cables are exposed along the leading edge of the lower planes.

Tail Unit.

The tail is unusual in shape to permit of economical folding.

The leading and trailing edges are parallel to the fore and aft line of the interplane struts when the machine is ready for stowage. The particular outline allows an uninterrupted edge even though the elevators are balanced and a reasonable proportion of length to breadth of the balanced part is maintained.

The tail plane is joined to the fuselage by fittings on the central rib, while the main spars are supported at their outer extremities by struts.

Those on the underside of the tail plane are attached to the fuselage; while the two upper struts converge to a fitting at the top of the fin. The hingeing of the elevators to the tail plane and the rudder to the fin can be quickly carried out. The control cables, which run along inside the fuselage as already described, are then connected, an interesting feature being the flexible fairleads on the king posts. (See Fig. 13.)

This completes the rigging of the "Panther."

Generally the machine is handled in much the same manner as the "Camel," though as it is appreciably heavier more men will be required.

For transport by land the complete machine can be taken on a single lorry.

The first operation necessary is to bifurcate the "bus." This can be done either by slinging the machine or chocking it up under the propeller boss, a shaped trestle being placed under the rear bulkhead of the front portion of the fuselage.

In the former case ropes should be passed through the rings under the wing tips and held to keep the machine from swinging.

The controls inside the observer's cockpit should then be parted and, as a precautionary measure, identification colours painted on the respective turnbuckles, cables, and holes in the bulkhead at the rear of the observer's cockpit.

A great deal of time will be saved in re-assembling if a chart giving the overall lengths of the various turnbuckles before disconnection is pasted on the inside of the fuselage in a conspicuous place. By this means the re-truing of the tail and rudder are unnecessary on re-assembly.

These turnbuckles are being replaced in later types by a quick release device, as shown in Figure 14.

After bifurcation, the forward portion resting on the undercarriage, suitably chocked, is placed on the lorry with its planes in a longitudinal direction; while the aft portion, complete with the tail unit, can be carried at the rear under the lower plane.

The method of folding is similar to that of bifurcation, except that it is neither necessary to disconnect the controls nor undo the hinge bolts on the starboard side.

TWIN-ENGINED HEAVY BOMBER.

The Handley-Page type o/400, fitted with two 350 Rolls-Royce engines, is typical of this class and practically all the long range bombing work which has been carried out during hostilities has fallen to its lot. At the time it was produced this machine was the largest successful aeroplane built. In view of its size its construction and erection called for treatment on a different scale from that previously in use and the general methods usually employed were adapted to suit its size. (See Figs. 15 and 16.)

Although the width when folded is only 17ft. 6in., the span with wings spread is about 100ft.; the length 63ft.; while the height is 18ft. 6in.; or, in other words, it has more than five times the span, four times the length, and three and a half times the height of the smallest machine made.

The weight empty with water is 8,500 lbs.; but when fully loaded is approximately 13,500.

Fuselage.

The "one piece" fuselage, as in small machines, was found to present numerous difficulties and a new mode of construction became necessary. The body is made up of three distinct sections, not only because material more suitable for this form of construction is available, but also in order to ensure greater accuracy in workmanship and ease of handling during assembly. The various sections are built and trued up separately, on the same principles as those employed for small machines. The construction is of the ordinary type, *i.e.*, four main longerons connected by vertical and transverse struts rigidly braced together. (See Fig. 17.) Truing up is commenced by clamping straight edges to the extreme vertical struts of each section so that certain marked points on the struts coincide with their upper edges; a string line is run between them on each side of the section in hand, and the complete unit placed so that these lines are horizontal.

The internal cross bracing wires are then adjusted until corresponding diagonals are equal.

The top and bottom transverse struts are marked at definite points and a string is placed longitudinally along the top of the skeleton body. These marks are then made to coincide with the string by means of the top cross bracing wires.

The bottom cross bracing wires are similarly treated, and plumb lines dropped from the top string, show when the underside of the fuselage is in truth. The sides are then trued up in like manner.

The forward or nose section, the middle section in which the tanks and bomb frames are carried, and the tail portion are then joined, and the whole structure trued in one.

The fuselage should then be placed on trestles by means of block and tackle and adjusted to flying position.

Erection of Centre Sections and Power Plant.

The lower centre section planes are first attached, after which the engines, which have meanwhile been rigged on the nacelle frames in "jigs," are fitted to the machine. Each engine is carried on horizontal bearer tubes, the radiator being supported on the bearers in front, while the oil tank is clamped to the upper V struts aft. Thus each nacelle complete with engine, radiator, oil tank, supports, and rear interplane strut forms a separate unit which is put on the machine in one piece and can be detached as a whole. (See Fig. 18.) The rigging of the upper centre section follows, after which both upper and lower sections are trued up.

For this purpose special trammels are provided by which the distances between the mid-point of the upper leading edge and particular points on the lower leading edge are measured. Landing wires are adjusted until these are equal.

Checking is done by plumb lines dropped from the upper leading edge, while a straight edge and spirit level show when the front spars are horizontal.

As no stagger is required, these plumb lines should touch both the upper and lower leading edges.

The correct incidence is given in the usual way by the adjustment of the incidence wires.

Controls, water, petrol and oil systems, and the various fuselage fittings and accessories are then fitted and the machine is ready for fixing the tail.

Tail Unit.

The biplane tail is actually composed of one upper plane and elevator, two lower planes and elevators, two rudders, and a central fin. (See Fig. 19.)

The four inner tail struts are attached to the fuselage and the two lower tail planes placed in position, the landing wires being loosely connected. The outer struts are attached to the upper tail plane, which is lifted into position with the struts suspended for attachment.

The fitting of the elevators to the rear spars, the rudders to their hinges, and the central fin between the fuselage and upper plane, present no difficulties.

The whole tail is then trued up by the usual methods.

Chassis.

The chassis is formed of two parts each placed between an engine nacelle and the fuselage. (See Fig. 20.)

The tubular struts arranged in the form of a pyramid are of definite length so that no adjustment is necessary, or indeed possible.

The wheels are carried on axles pivoted at the centre, while substantial shock absorbers covered by streamline fairing are fitted on the outside.

After assembly the axles should be checked for alignment by plumb lines dropped from the leading edge of the lower main planes.

Main Planes.

The main planes are of interest. They are made to fold back from the centre section by means of hinges. The upper and lower planes can be assembled as complete units on "jigs," thus ensuring absolute truth before they are rigged to the machine. (See Fig. 21.)

An alternate method is to erect them, lower planes first, as in the case of smaller machines; but this operation, of necessity, entails much time and labour.

The wings are lifted into position by means of blocks and chains, the king posts which support the overhang forming a good point of attachment.

Securing rods inserted at the hinges join the wing spars to the centre sections.

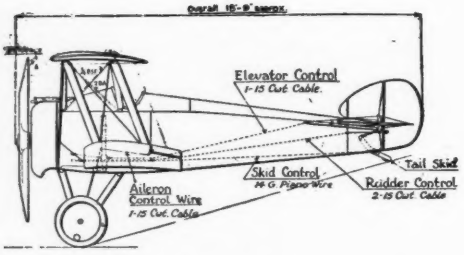
Truing up is carried out by the normal methods already described for the "Camel." Care should be taken that the balanced ailerons on the upper planes are adjusted so that their trailing edges are level with that of the main planes when the "joy stick" is neutral.

Miscellaneous.

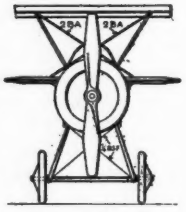
Throughout the process of assembly and rigging one point above everything else should be borne in mind; it is that should anything at all in the machine subsequently shake loose or come adrift great inconvenience if not actual danger is the result. The perfect condition of control wires, the locking of bolts, turnbuckles, streamline wires, have already been dealt with, but it may not at first occur to the inexperienced rigger to see that seat cushions are firmly strapped in, safety belts properly fitted, and any extra equipment carried, so attached, that the most violent manœuvre cannot displace them.

The exposure to weather which all aeroplanes undergo necessitates constant attention to all parts. Machines should be wiped down every day and a thorough search made for any defects. Tyres should be kept at a constant pressure, fabric periodically examined for "sogginess," air bags tested by frequent inflation, and shock absorbers replaced as soon as the outer covering shows signs of perishing. The least sign of rust on any metal work should be immediately scraped away and the part re-painted. Pivots or bearings should be kept well greased. This applies particularly to the undercarriage wheels, for should a wheel stick when taking off from the ground or the deck of a ship the results may be distinctly unpleasant.

In fine, inspection is as important during the life of a machine as during its construction.



SIDE ELEVATION



FRONT ELEVATION
(LESS MAIN PLANES)

Flying Position:
To get Machine in Flying Position, level transversely across the lower Front Spar in Fuselage and longitudinally across the upper surface of the Top Longerons in the Pilot's Cockpit.

Truing up Fuselage:
The Fuselage is symmetrical in plan view and from Strut No 6 to Rudder Post in Side Elevation.
Mark points on Side Struts so that these points are on the Thrust Line in Side Elevation (*for distances below the upper face of the Top Longerons see Table A Sheet 4.*)
Make Internal Cross Bracing Wires equal at each section. Check by Trammel.
Make Top Cross Bracing Wires equal in each Bay. Similarly make Bottom Cross Bracing Wires equal in each Bay. Check by Trammel. True up by Side Bracing Wires until all marked points on Side Struts are in line in Side Elevation, levelling from marked point to marked point on adjacent Side Strut and checking each Side Strut for being Vertical.

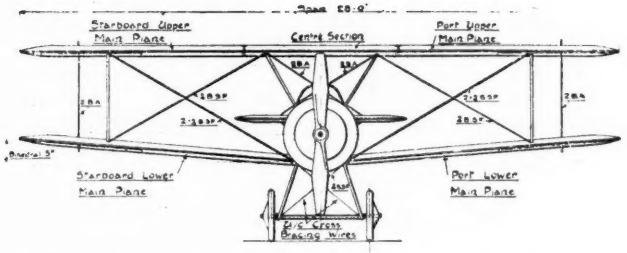
Truing up Undercarriage:
True up until Cross Bracing Wires are equal. Check by Trammel.

Truing up Centre Section:
The Centre Section is symmetrical about the Vertical centre line of Machine. Adjust by Centre Section Cross Bracing Wires until Upper Wires are equal and Lower Wires are equal. Check by Trammel.
The Stagger of the Centre Section is 18". Check after fitting Lower Main Planes and adjust by Centre Section Stagger Wires.

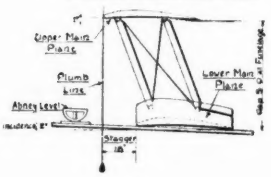
4 Sheets
Sheet 1.

FIG. 1.

Rigging Diagrams of Sopwith "Camel" (Side and Front Elevations).



POSITION OF UPPER MAIN PLANE IN RELATION TO LOWER MAIN PLANE



4 Sheets.
Sheet 2.

MAIN PLANES

The Leading Edge of Upper Main Planes is straight in plan view & viewed from front. The Leading Edge of Lower Main Planes is symmetrical about centre line of Machine Drop Plumb lines on each side from the Leading Edge of the Upper Main Planes. These lines must be in line viewed from the side.

Dihedral
The Dihedral of the Lower Main Planes = 5° Check by Abney Level and Straightedge along the Spars. There is no Dihedral on the Upper Main Planes.

Stagger The Stagger is 18" at Centre Section and 18" at Outer Struts. Check by measuring the horizontal fore and aft distances between the Plumb lines and the leading Edge of Lower Main Planes.

Incidence
The Incidence is 2° throughout Upper & Lower Main Planes. Check by Straightedge and Abney Level from Leading Edge to Trailing Edge at Ribs.

Ailerons
There is no Droop on the Ailerons with Pilot's Control Stick Central.

FIG. 2.

Rigging Diagram of Sopwith "Camel" (Front Elevation).

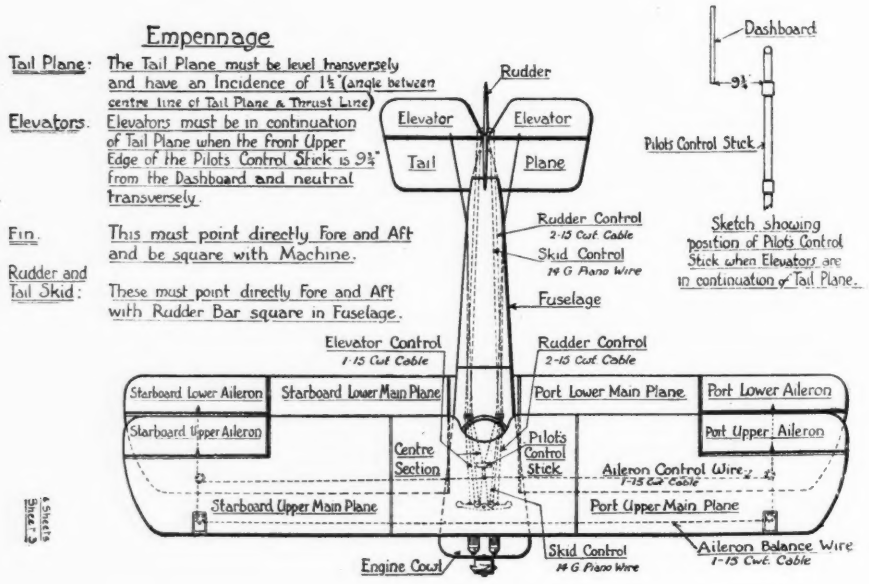

Empennage
Tail Plane: The Tail Plane must be level transversely and have an Incidence of 1½° (angle between centre line of Tail Plane & Thrust Line)
Elevators. Elevators must be in continuation of Tail Plane when the front Upper Edge of the Pilots Control Stick is 9¼" from the Dashboard and neutral transversely.
Fin. This must point directly Fore and Aft and be square with Machine.
Rudder and Tail Skid: These must point directly Fore and Aft with Rudder Bar square in Fuselage.
Rudder
Elevator
Elevator
Tail
Plane
Dashboard
9¼
Pilots Control Stick
Sketch showing position of Pilots Control Stick when Elevators are in continuation of Tail Plane.
Rudder Control 2-15 Cwt. Cable
Skid Control 14 G Piano Wire
Fuselage
Elevator Control 1-15 Cwt Cable
Rudder Control 2-15 Cwt. Cable
Starboard Lower Aileron
Starboard Lower Main Plane
Port Lower Main Plane
Port Lower Aileron
Starboard Upper Aileron
Port Upper Aileron
Centre Section
Pilots Control Stick
Aileron Control Wire 1-15 Cwt. Cable
Starboard Upper Main Plane
Port Upper Main Plane
Aileron Balance Wire 1-15 Cwt. Cable
Engine Court
Skid Control 14 G Piano Wire
6 Sheets Sheet 3

FIG. 3.

Rigging Diagram of Sopwith "Camel" (General Plan).

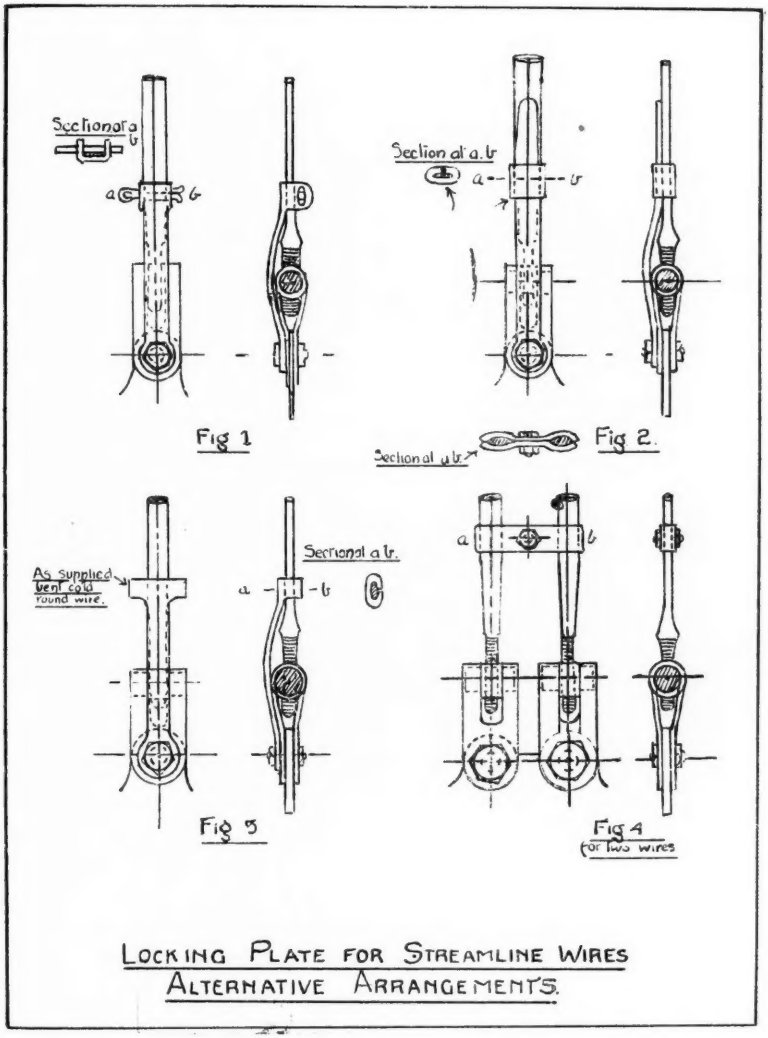

Sectional a b
a
b
Fig 1
Sectional a b
a
b
Fig 2.
Sectional a b
As supplied bent cold round wire.
a
b
Sectional a b.
Fig 3
a
b
Fig 4
for Two wires
LOCKING PLATE FOR STREAMLINE WIRES
ALTERNATIVE ARRANGEMENTS.

FIG. 4.

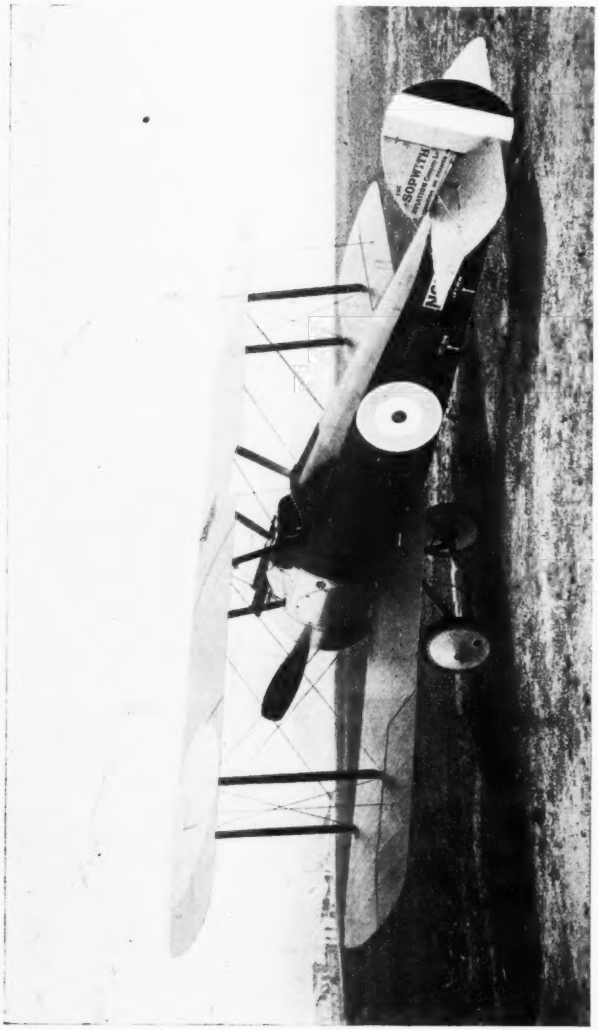


FIG. 5.

Sopwith Biplane F.1 (Camel) with 130 h.p. Clerget Engine.

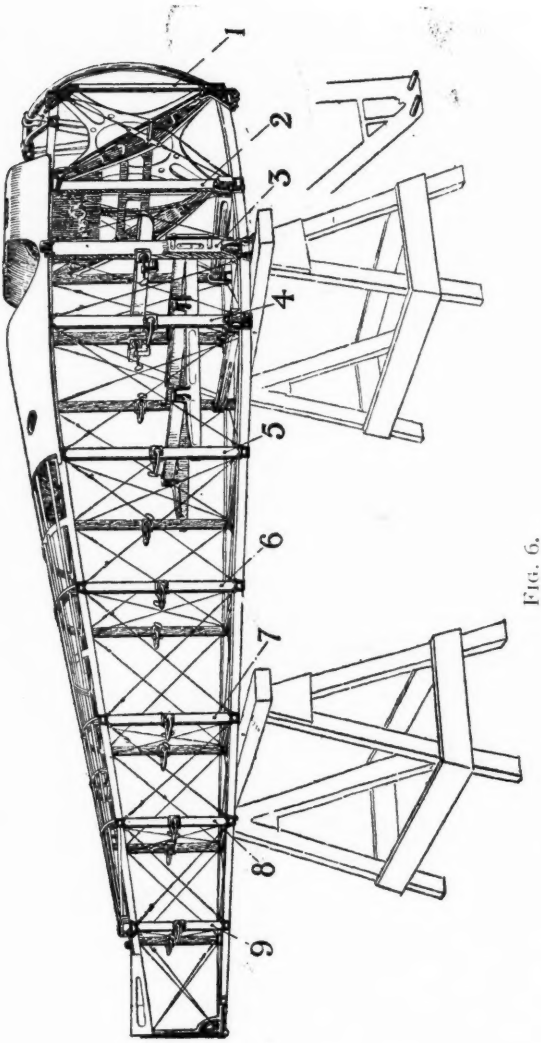


FIG. 6.

Skeleton fuselage, showing method of "truing up" by the aid of small blocks of wood clamped to the struts (Sopwith "Camel").

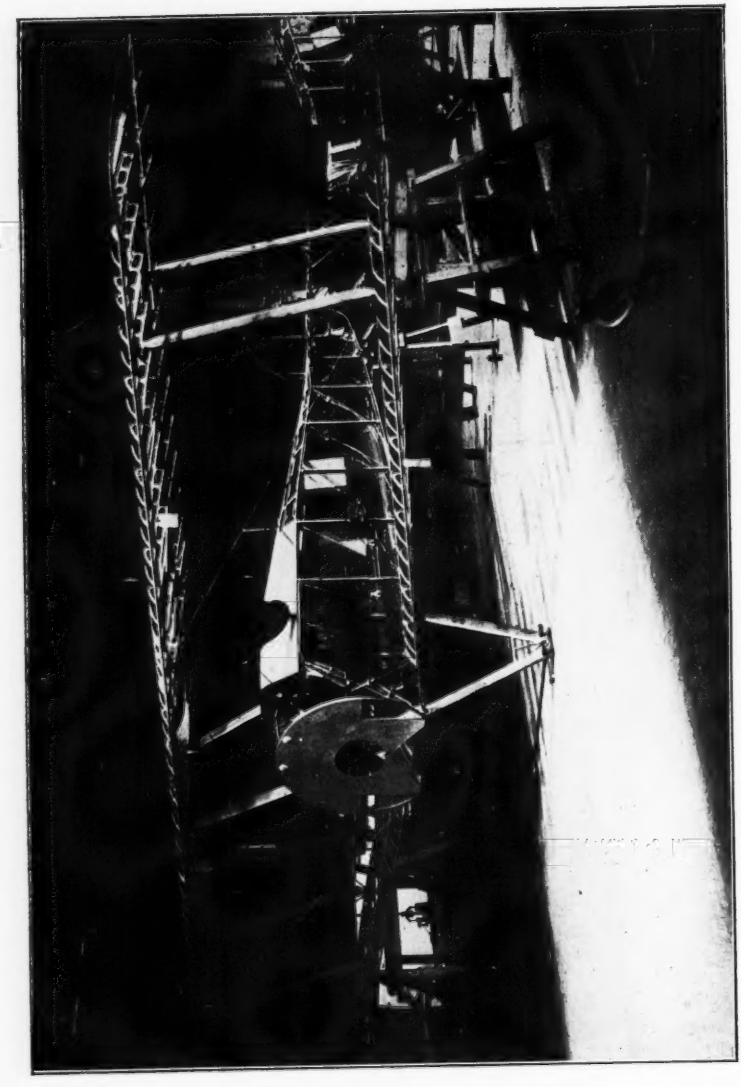


FIG. 7.
Preliminary erection of skeleton machine.

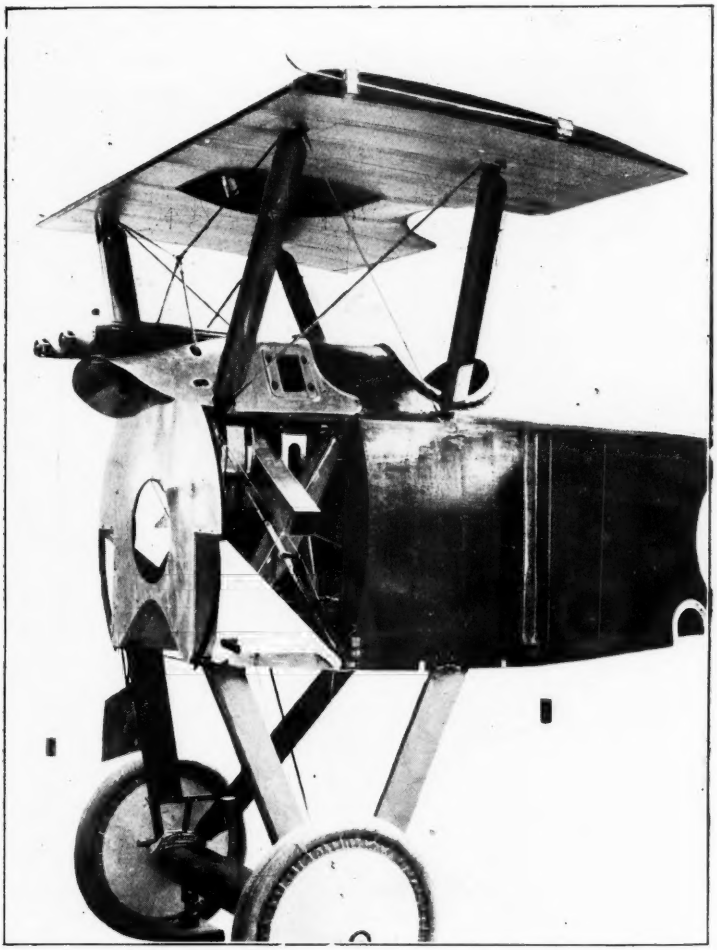


FIG. 8.

Centre section, showing arrangement of cross bracing wire (Sopwith "Camel").

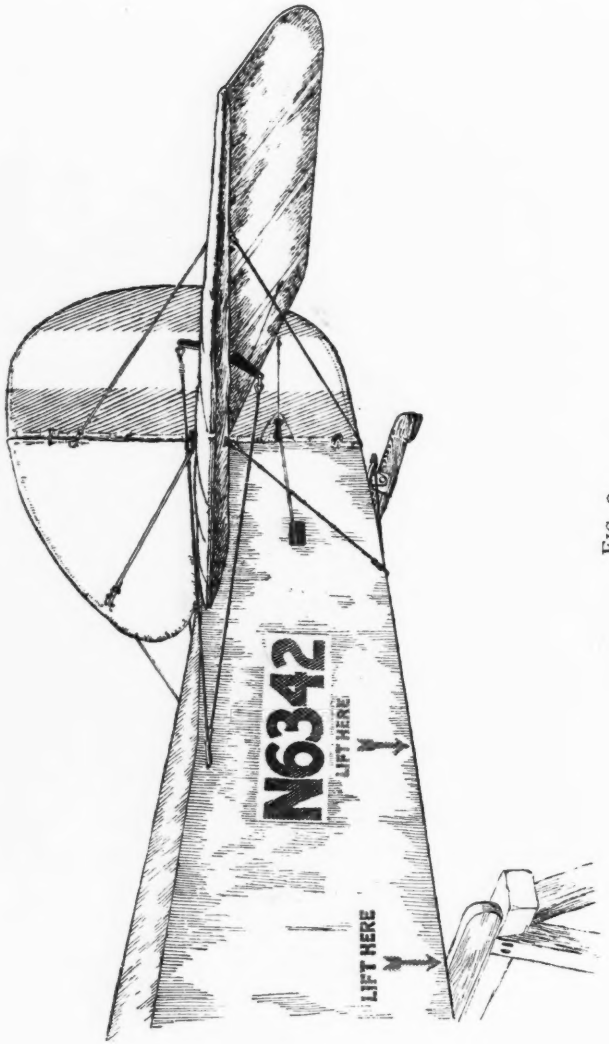


FIG. 9.
Tail unit of Sopwith "Camel."

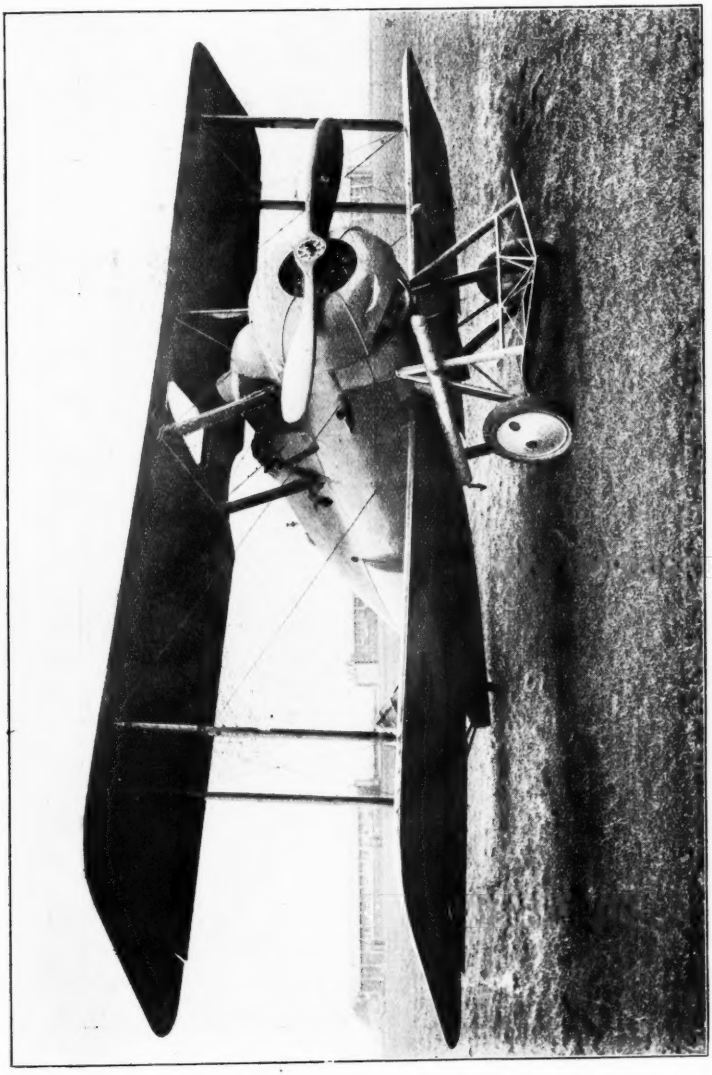


FIG. 10.

Parnall "Panther" Ship Aeroplane with 230 h.p. B.R.2 Engine.

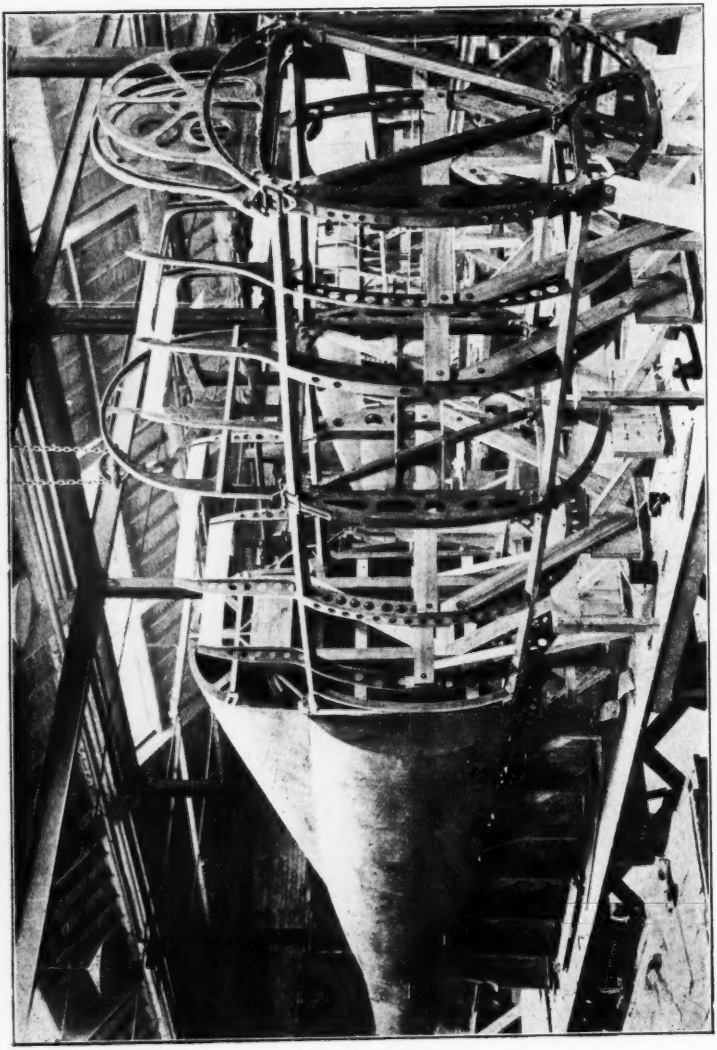


FIG. 11.
Fuselage of the Parnall "Panther," showing method of "jig-traing" during erection.

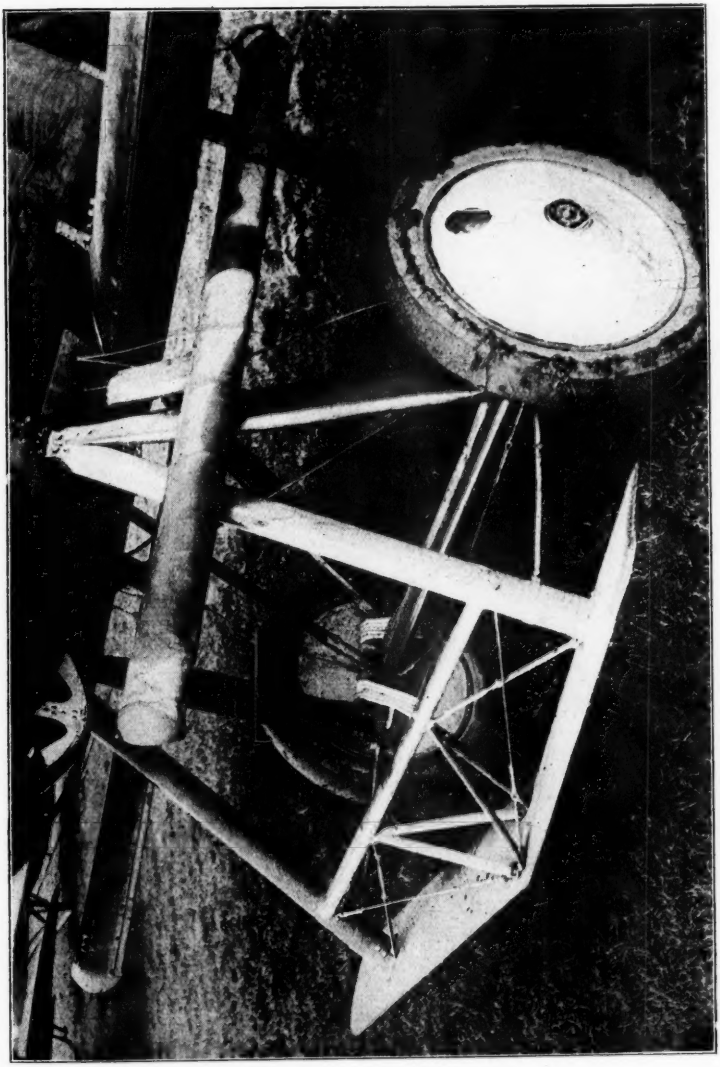


FIG. 12.

Under-carriage, showing hydrovane and air bags (Parnall "Panther").

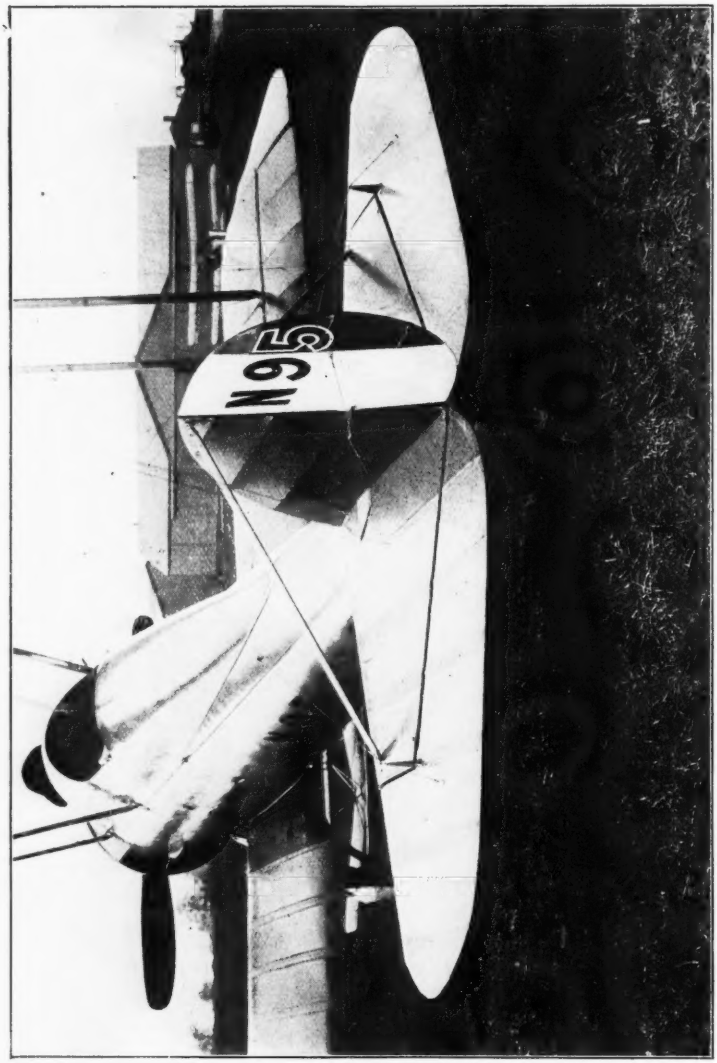


FIG. 13.
Tail unit of Parnall "Panther."

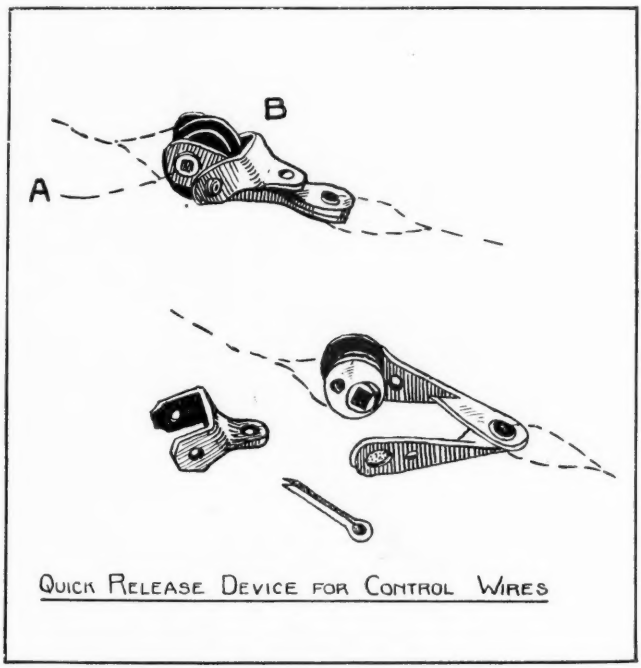


FIG. 14.

In the sketch the dotted lines represent the wires. A special key fits into the square hole at A and turns the small wheel B. As this is pivoted eccentrically the two wires are slackened off when it is turned, so that the device can be pulled apart, and the wires removed from the pulley wheel B.

FIG. 15.
Handley Page Machine, Type O/400.

FIG. 16.

Handley Page Machine, Type O/400, showing wings folded for storage.

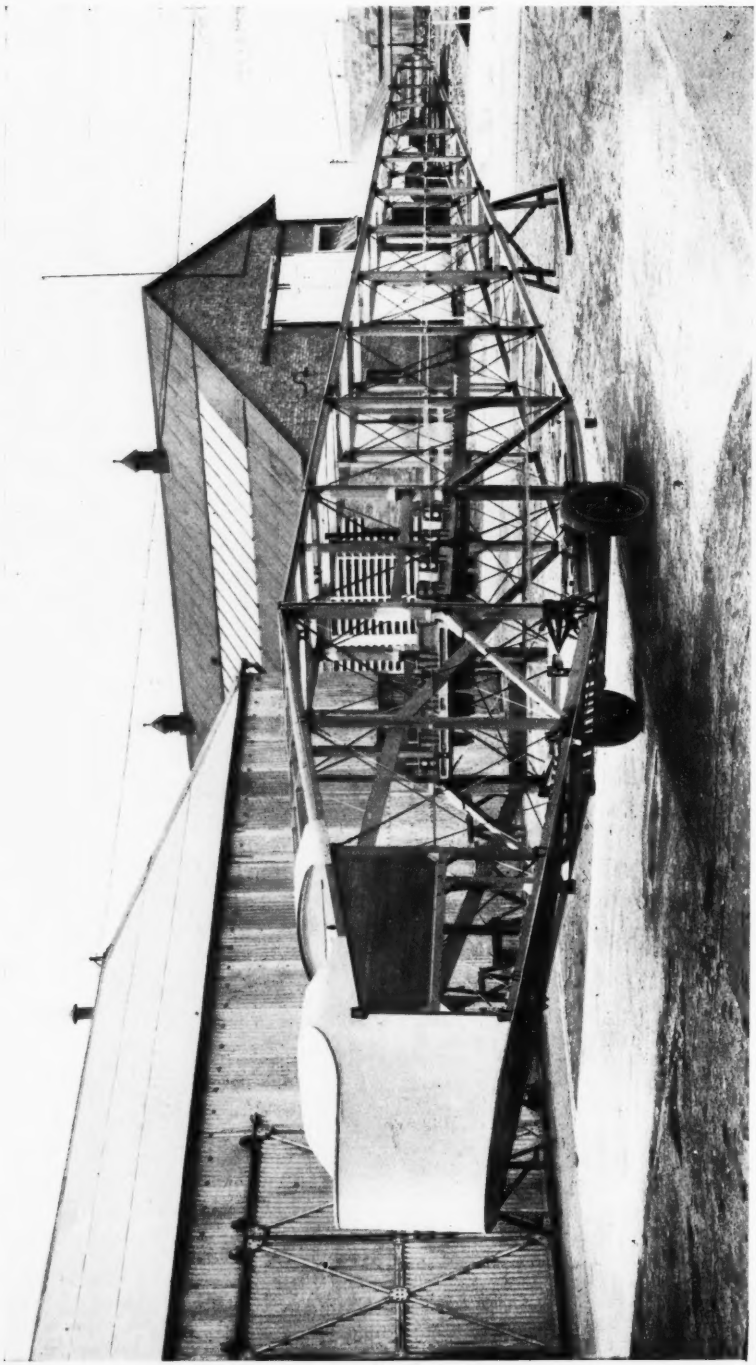


FIG. 17.
Skeleton fuselage (Handley Page, Type O/400).

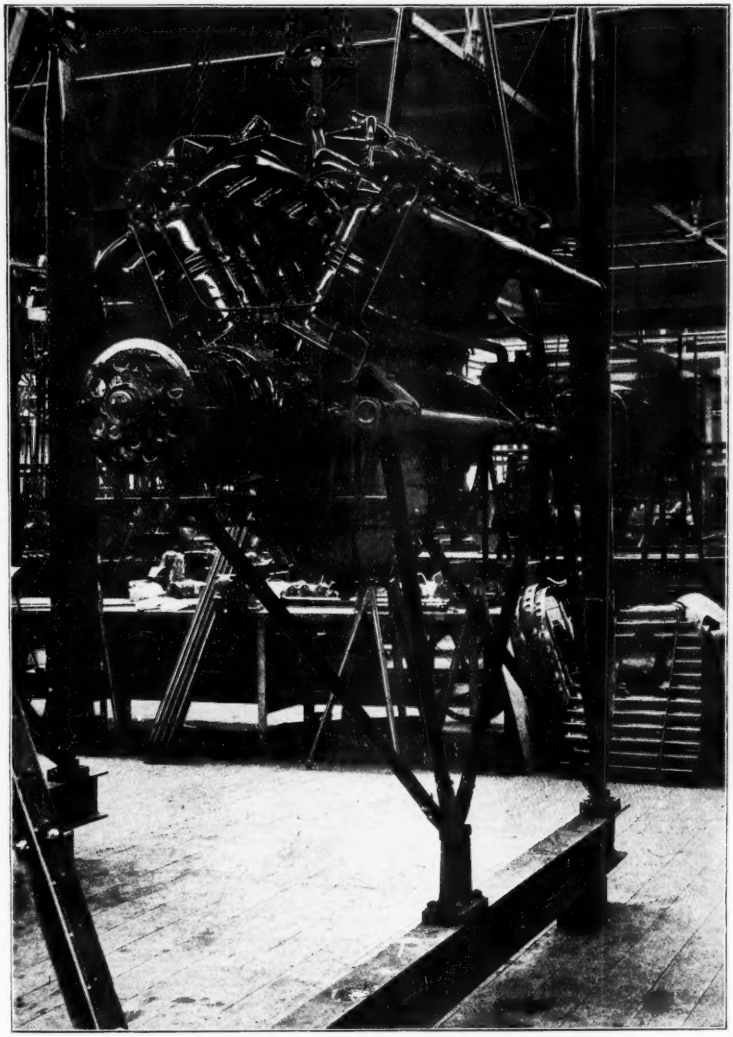


FIG. 18.

Engine unit complete with supports in jig (Handley Page, Type O/400).

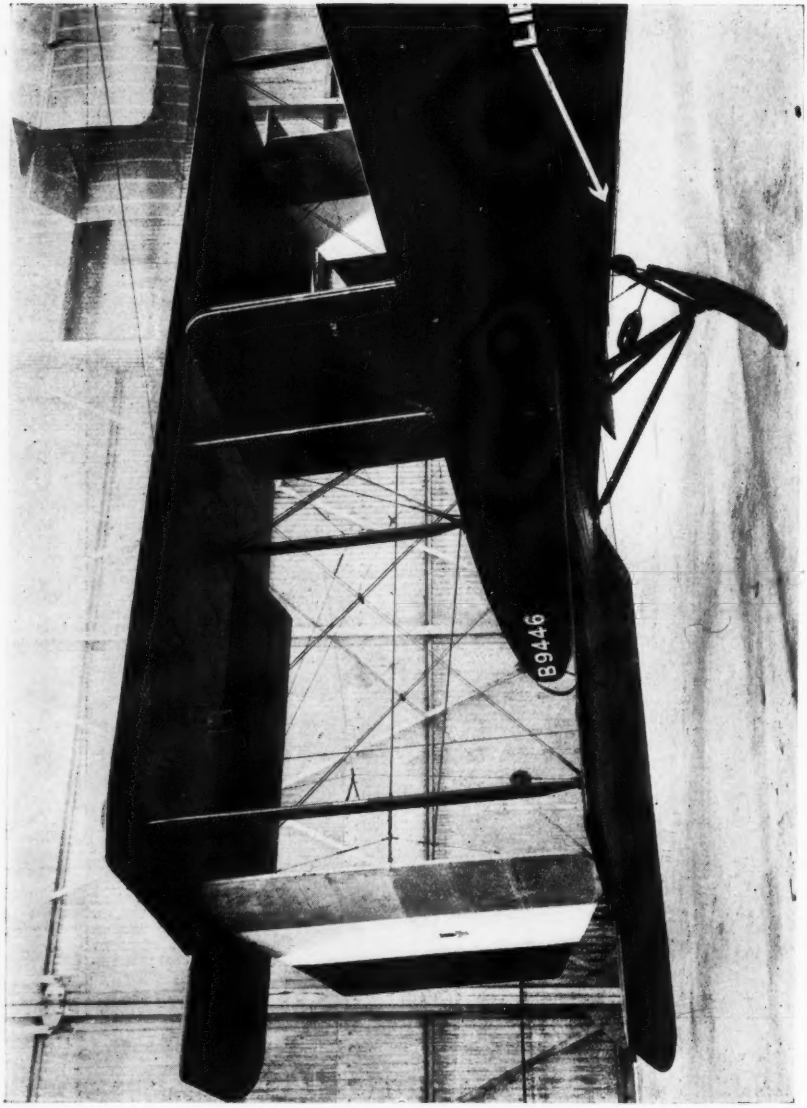


FIG. 19.
Tail unit complete (Handley Page, Type O/400).

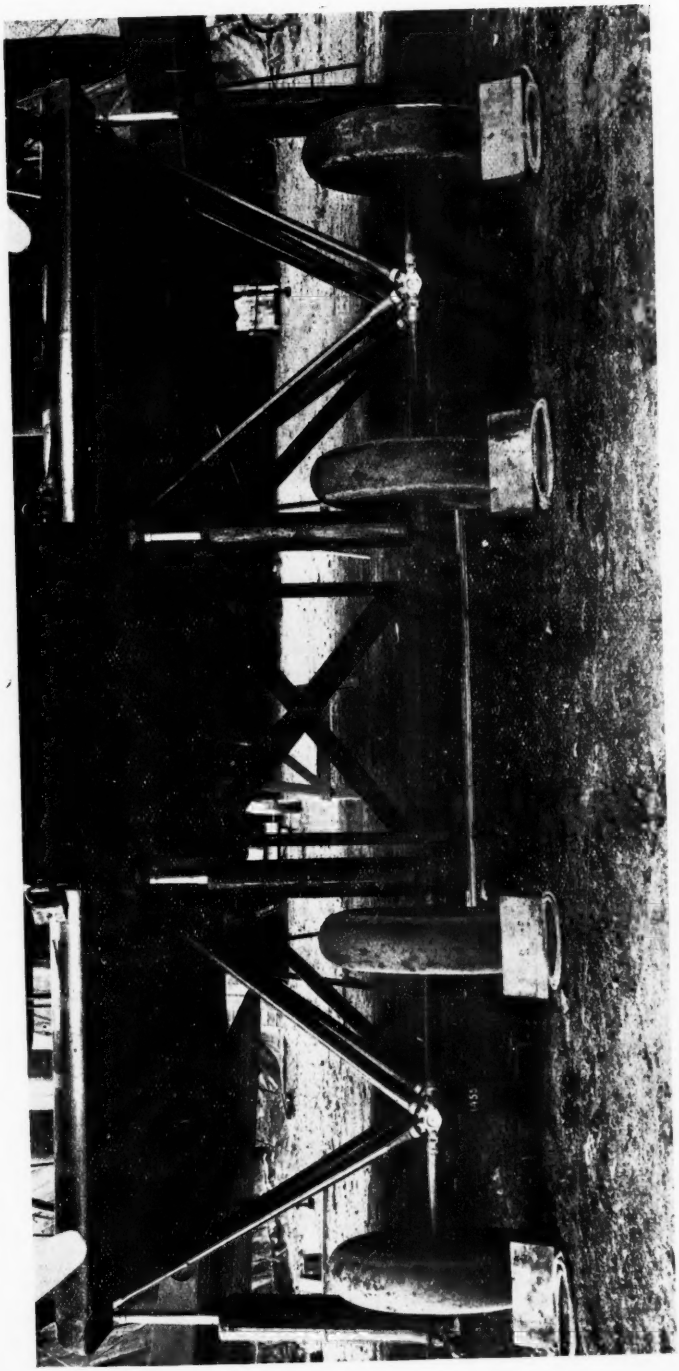


FIG. 20.

Chassis forming one complete unit (Handley Page, Type O/400).

FIG. 21.

Truing main planes in jigs (Handley Page, Type O/400).
Streamlined wire, locking device.

STRUTS OF CONICAL TAPER.

BY H. A. WEBB, M.A., ASSOCIATE FELLOW, AND MISS E. D. LANG, M.A.

Abstract.

The strength of wooden struts consisting of a parallel centre portion with ends of conical taper is considered mathematically. It is shown that the best results are obtained when the parallel portion is half the total length of the strut, and when the taper of the ends is such that the end diameter is half the central diameter. Such a strut is 12% lighter than a simple parallel strut of the same length and strength, and only 1% heavier than the ideal strut of the best possible gradual taper. A simple formula for design is given.

The authors suggest that struts of this pattern might be adopted, for manufacture reasons, in many parts of an aeroplane in which solid wooden struts are used, especially if of circular section. They can then be turned in the ordinary lathe.

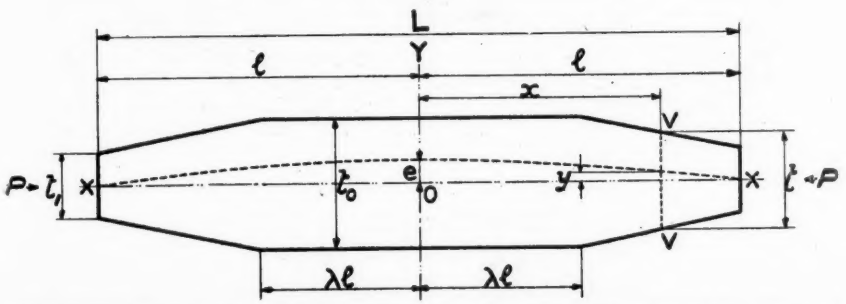
§ 1. Introduction.

A common type of fuselage struts in a tractor aeroplane consists of a parallel centre portion with two conical ends. The cross-section of the strut may be circular, square, or rectangular. In a pusher, such struts, of streamline section, are often used to support the outrigger booms. Less frequently, they are used as interplane struts in the wings; some Avro wing struts are of this type.

The ideal taper for struts, with rules for design, was fully explained in a recent number of the AËRONAUTICAL JOURNAL,* and struts of this pattern have been extensively used on British aeroplanes in the last few years.

The object of the present article is to show that struts of conical taper, *if correctly designed*, are only 1% heavier, and have, if exposed to the air, less than 1% more wind resistance than ideal struts; and to suggest their adoption, in the wings as well as in the fuselages of commercial aeroplanes, where simplicity of design and ease of manufacture and inspection may be of more importance than the saving of the last ounce of weight. It will be shown incidentally that faulty design may lead to a very inefficient strut, and easily to a strut that is actually heavier than a simple parallel strut of the same strength; so that a bad

FIG 1.

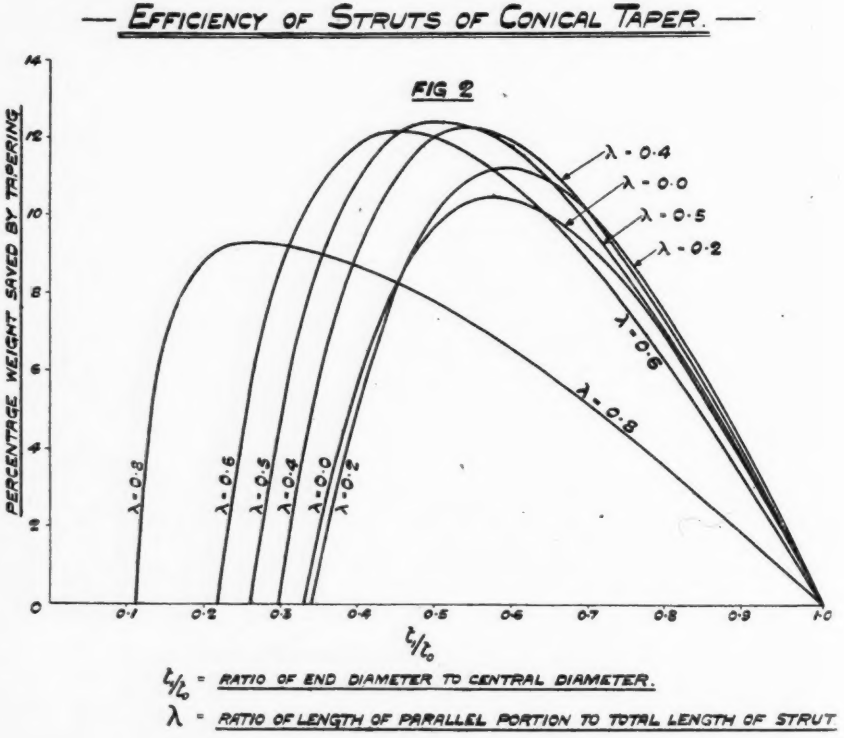


* Barling and Webb. "Design of Aeroplane Struts." "Aeronautical Journal," October, 1918.

taper may be worse than useless. This fact may be well known to designers, but we believe that this is the first time that figures have been given in support of it. (See § 5.)

§ 2. Notation.

The strut, Fig. 1, of length $L = 2l$ inches, is assumed to have frictionless pin-joints at its ends XX. Axes OX, OY, are taken as in the figure. The strut



deflects under a given central end load P lb. E lb. per sq. in. is Young's modulus of elasticity for the material. For the cross-section VV of the strut distant x inches from O, the centre of the strut,

Maximum thickness perpendicular to the neutral axis = t inches.
Moment of inertia of cross-section about neutral axis = I inch units.
(The neutral axis is perpendicular to the plane of the paper.)
Area of cross-section ... ... = A sq. in.
Deflection under load P ... ... = y inches.

t, I and A have the values t_0, I_0 and A_0 in the parallel portion, and t_1, I_1 and A_1 at the ends of the strut.

The length of the parallel portion = $\lambda L = 2\lambda l$ inches.

All the cross-sections of the strut are assumed to be similar and similarly situated, so that

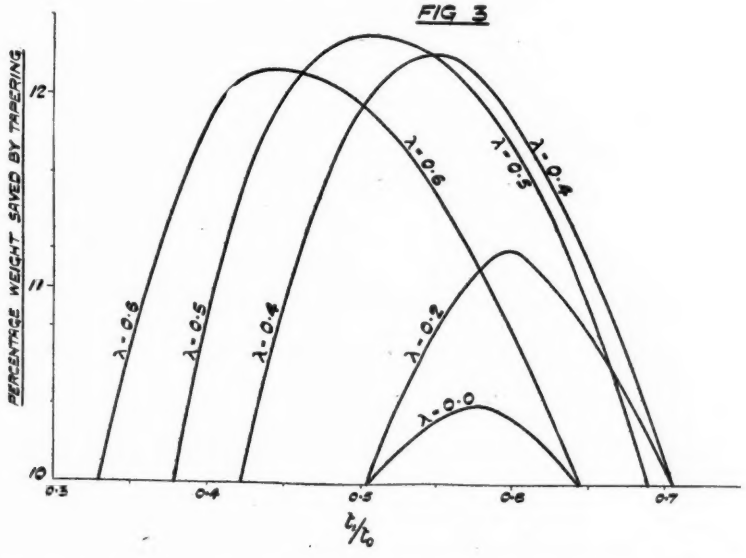
$$A = at^2$$
$$I = bt^4$$

where a and b are numerical constants, given by the following table:—

	a	b
Streamline section, fineness ratio 3, about	2.18	0.130
Circular section	$\frac{\pi}{4}$	$\frac{\pi}{64}$
Square section	1	$\frac{1}{12}$
Rectangular section, sides a and d $(a > d)$	$\frac{a}{d}$	$\frac{a}{12d}$

§ 3. Rules for Design.

We wish to choose λ, t_0 and t_1 to the best advantage, for given values of P, L and E. This problem is solved in the Appendix, and the results are shown



graphically in Fig. 2. The most interesting parts of the curves in Fig. 2 are shown in Fig. 3 on a larger scale, and it is seen that the best results are obtained when both λ and t_1/t_0 are very nearly equal to 0.5, when over 12% of weight is saved by tapering; though any value of λ between 0.4 and 0.6 is nearly as good, *provided* t_1/t_0 *is suitably chosen.*

We deduce the following rules for the design of struts of conical taper:—

(i.) *The parallel portion should be one half the total length of the strut.*

(ii.) *The taper should be so chosen that the end diameter* t_1 *of the strut is half the diameter* t_0 *of the parallel portion.*

(iii.) *The diameter* t_0 *of the parallel portion is given by*

$$P = \frac{8EI_0}{L^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

It should be noticed that these results are established in the Appendix for *long* struts only, to which Euler's theory of failure is applicable. A rough rule for spruce is that the length should exceed twenty least central diameters ($L > 20t_0$). For shorter or stiffer struts the formula (1) gives too high a value of the crippling load, and should not be used.

§ 4. Numerical Examples.

EXAMPLE 1.

To design a solid wooden pin-jointed streamline strut (fineness ratio 3) of conical taper, 70 inches long, to have a crippling load of 2,000 lbs. It is given that

$$E = 1.6 \times 10^6 \text{ lbs. per square inch.}$$

We have $P = 2{,}000$ lbs.
and $L = 70$ inches.

From (1) I_0 is given by

$$P = \frac{8EI_0}{L^2}$$

$$\therefore I_0 = \frac{2{,}000 \times (70)^2}{8 \times 1.6 \times 10^6} = 0.7656$$

But from the table in § 2,

$$I_0 = 0.130\, t_0^4.$$
$$\therefore t_0 = 1.558 \text{ inches.}$$
$$\therefore t_1 = \tfrac{1}{2}t_0 = 0.779 \text{ inches.}$$

Hence the strut should consist of a parallel centre portion, 35 inches long and 1.56 inches thick; and two conical ends, each $17\frac{1}{2}$ inches long, tapering to an end thickness of 0.78 inches.

This strut has 12 per cent. less weight and 8 per cent. less air resistance than a parallel strut of the same material.

EXAMPLE 2.

To design a solid wooden pin-jointed strut of circular section and conical taper, 30 inches long, to have a crippling load of 1,000 lbs. It is given that

$$E = 1.6 \times 10^6 \text{ lbs. per sq. in.}$$

We have

$$P = 1{,}000 \text{ lbs.}$$
$$\text{and } L = 30 \text{ inches.}$$

From (1) I_0 is given by

$$P = \frac{8EI_0}{L^2}$$

$$\therefore I_0 = \frac{1{,}000 \times (30)^2}{8 \times 1.6 \times 10^6} = 0.07031$$

But from the table in § 2,

$$I_0 = \frac{\pi}{64} t_0^4.$$
$$\therefore t_0 = 1.094 \text{ inches.}$$
$$\therefore t_1 = \tfrac{1}{2}t_0 = 0.547 \text{ inches.}$$

Hence the strut should consist of a parallel centre portion, 15 inches long, of diameter 1.094 inches, and two conical ends, each $7\frac{1}{2}$ inches long, tapering to an end diameter of 0.547 inches.

This strut weighs 12 per cent. less than a parallel strut of the same material.

§ 5. Danger of Faulty Taper.

It is seen from Fig. 2 that if the taper is too severe the advantage of tapering is less, and may disappear altogether, so that the tapered strut may be heavier than the equivalent parallel strut. In fact it can be shown mathematically that the curves in Fig. 2 drop to minus infinity as t_1/t_0 approaches zero, so that a strut of this pattern with pointed ends will support no load at all. It may, of course, be argued that this is because the ends will crush; but that is only part of the explanation. An erroneous view, commonly held a few years ago, was that if the ends were strong enough to resist crushing, and if the middle of the strut was stiff enough to resist bending, any reasonable taper would yield a satisfactory strut. The fallacy in this view lies in the fact that the strut must be stiff enough to resist bending *all along its length*; otherwise the stiffest part of the strut will be inefficiently employed.

For example, suppose the strut in Example 1, § 4, were designed in this way. Assuming a maximum allowable compressive stress of 5,500 lbs. per sq. in., we find that $t_1 = 0.41$ inches.

If $\lambda = 0.5$, $t_0 = 1.81$ inches and $t_1/t_0 = 0.23$, such a strut (see Fig. 2) is actually 7% heavier than a simple parallel strut, so that tapering has proved worse than useless. For smaller values of λ the result is still more striking.

For instance, if $\lambda = 0.2$, it can be proved that t_0 must be as large as $2\frac{1}{2}$ inches to support the load and the strut would be 50% heavier than a simple parallel strut!

This example shows the danger of too sharp a taper. The inference is that when a conical taper is used the ends should generally be larger than the crushing load would indicate.

MATHEMATICAL APPENDIX.

In Fig. 1, we have

$$t = \frac{(l - x)\,t_0 + (x - \lambda l)\,t_1}{l\,(1 - \lambda)} \qquad . \quad . \quad . \quad . \quad . \quad (2)$$

From $x = 0$ to $x = \lambda l$, the bending moment equation is

$$EI_0 \frac{d^2y}{dx^2} = -Py \qquad . \quad . \quad . \quad . \quad . \quad (3)$$

and from $x = \lambda l$ to $x = l$,

$$EI \frac{d^2y}{dx^2} = -Py,$$

$\therefore$ from (2)

$$EI_0 \left\{ \frac{(l - x)\,t_0 + (x - \lambda l)\,t_1}{l\,(1 - \lambda)\,t_0} \right\}^4 \frac{d^2y}{dx^2} = -Py \qquad . \quad . \quad . \quad (4)$$

$$\left.\begin{aligned} &\text{At } x = 0,\ y = e \\ &\frac{dy}{dx} = 0 \end{aligned}\right\} \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

$$\text{At } x = \lambda l,\ y \text{ and } \frac{dy}{dx} \text{ are continuous} \quad . \quad . \quad . \quad . \quad (6)$$

$$\text{At } x = l,\ y = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

The solution of the differential equations (3) and (4), subject to the conditions (5), (6) and (7), will give a formula for P, the crippling load of the strut. All angles are expressed in radians.

If

$$\frac{P}{EI_0} = \frac{k^2}{l^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

we have from (3) and (5), by integration,

$$y = e \cos \frac{kx}{l}, \text{ from } x = 0 \text{ to } x = \lambda l,$$

and at $x = \lambda l$,

$$\left.\begin{aligned} y &= e \cos k\lambda \\ \frac{dy}{dx} &= -\frac{ek}{l} \sin k\lambda \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad . \quad (9)$$

From $x = \lambda l$ to $x = l$, we find by integrating (4) and making use of (7), after some reduction,

$$Cy = \{ (l - x)\, t_0 + (x - \lambda l)\, t_1 \} \sin \frac{k\,(1-\lambda)\, t_0^2\, (l-x)}{t_1\, [(l-x)\, t_0 + (x - \lambda l)\, t_1]}$$

where C is a constant of integration.

Hence, when $x = \lambda l$,

$$\left.\begin{aligned} Cy &= l\,(1-\lambda)\, t_0 \sin \left[\frac{kt_0}{t_1}(1-\lambda)\right] \\ \text{and} \\ C\frac{dy}{dx} &= -(t_0 - t_1) \sin \left[\frac{kt_0}{t_1}(1-\lambda)\right] \\ &\quad - k(1-\lambda)\, t_0 \cos \left[\frac{kt_0}{t_1}(1-\lambda)\right] \end{aligned}\right\} \quad . \quad . \quad . \quad (10)$$

Hence, from (9) and (10), either $e = C = 0$ and the strut does not deflect, or

$$k \tan k\lambda = k \cot \left[\frac{kt_0}{t_1}(1-\lambda)\right] + \frac{1 - t_1/t_0}{1-\lambda} \quad . \quad . \quad (11)$$

gives P, the crippling load of the strut.

Let now W lb. be the weight of the strut, and W^1 lb. the weight of a parallel strut of the same length, material, crippling load and sectional shape; *i.e.*, W^1 is the weight of the parallel strut that the tapered strut is designed to replace.

If A^1 and I^1 have the usual meanings for the parallel strut,

$$P = \frac{\pi^2 E I^1}{L^2},$$

$\therefore$ from (8)

$$\frac{I^1}{I_0} = \frac{4k^2}{\pi^2}$$

$$\therefore \frac{A^1}{A_0} = \frac{2k}{\pi}$$

But if w lb. per cubic inch is the density of the material,

$$W^1 = wA^1L$$

$$\text{and } W = wA_0L\left\{\lambda + \tfrac{1}{3}(1-\lambda)\left(1 + \frac{t_1}{t_0} + \frac{t_1^2}{t_0^2}\right)\right\}$$

$$\therefore \frac{W}{W^1} = \frac{\pi}{2k}\left\{\lambda + \tfrac{1}{3}(1-\lambda)\left(1 + \frac{t_1}{t_0} + \frac{t_1^2}{t_0^2}\right)\right\}$$

Hence, if p is the percentage weight saved by tapering,

$$1 - \frac{p}{100} = \frac{\pi}{2k}\left\{\lambda + \tfrac{1}{3}(1-\lambda)\left(1 + \frac{t_1}{t_0} + \frac{t_1^2}{t_0^2}\right)\right\} \quad . \quad . \quad (12)$$

To find numerical values, it is necessary to solve equation (11), when two of the three quantities k, λ and t_1/t_0 are known. This may be done as follows:—

Introduce two auxiliary variables u and v, defined by

$$u = \frac{kt_0}{t_1}(1-\lambda) \quad . \quad . \quad . \quad . \quad . \quad (13)$$

and

$$v = \frac{1}{k(1-\lambda)} - \tan \lambda k \quad . \quad . \quad . \quad . \quad (14)$$

Then from (11)

$$v = \frac{1}{u} - \cot u \quad . \quad . \quad . \quad . \quad . \quad (15)$$

Time is saved by tabulating the function

$$\frac{1}{u} - \cot u.$$

If now any suitable values of λ and k are chosen, v is found from (14), u is found from the table, t_1/t_0 is found from (13), and p is found from (12). From numerical data so obtained the curves in Figs. 2 and 3 have been drawn.

It is seen from Fig. 3 that the values

$$\lambda = 0.5$$

$$\text{and } \frac{t_1}{t_0} = 0.5$$

give the best result, viz.,

$$p = 12.35.$$

Taking these values we find that

$$W = \frac{19}{24} wA_0L$$

and $$W = (0.8765)\, W^1.$$

But $$W^1 = wA^1L$$

$$\therefore A_0 = (1.107)\, A^1$$

and

$$\therefore I_0 = (1.226)\, I^1$$

but

$$P = \frac{\pi^2 EI^1}{L^2}$$

$$\therefore P = (8.05)\frac{EI_0}{L^2}$$

$\therefore$ by writing, for purposes of design,

$$P = \frac{8EI_0}{L^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

we are making a small error on the side of safety.

PROCEEDINGS.

SEVENTH MEETING, 54th SESSION.

The Seventh Meeting of the Session was held in the Theatre of the Royal Society of Arts, London, on Wednesday, January 29th, 1919, Mr. L. BAIRSTOW, F.R.S., presiding.

The CHAIRMAN announced that the Lecture by Mr. Grahame-White which had been previously announced to be delivered in December last, but which in consequence of the General Election had been postponed, would be delivered on February 19, with General Seely in the chair.

The subject of "The Rigging of Aeroplanes," upon which Captain Crouch would lecture that evening, was one of the newer developments of aeronautics. Always important, it had become increasingly important as the number of machines produced per month was increased. Captain Crouch's experience probably carried him back to the period in which rigging instructions, as they were now known, did not exist. His early experience was obtained mostly with French aviation firms, and the outbreak of war found him near Paris with a good deal of knowledge of aeronautics on his hands. It would be remembered that war was declared on France two or three days before Britain joined the campaign, and during that period France was in an excited state. Consequently Captain Crouch's passage from Paris to Boulogne was not a normal or an ordinary one, and for one short period in the middle of the journey he found himself in the hands of the police as a suspected spy, but finally he got to Boulogne and home, and joined the Royal Naval Air Service. A little later he became associated with Colonel Ogilvie and the repair depôt at Dunkirk. The squadron at Dunkirk had done very useful work, and the pioneer squadron was a thorn in the side of the Germans throughout the whole period of the war. In that early period Captain Crouch was associated with the repair and general assembly of the aeroplanes delivered from England. Drawings and spare parts were few, and standard parts were still fewer; so that, even at that period, rigging was by no means the art that it was at the present time. He thought Captain Crouch's lecture dealt chiefly with rigging as we now knew it. One of his latest duties before the signing of the Armistice was the working out of some technical details of the bombing squadron which was to attack Berlin. No doubt that would lead anybody to appreciate the importance of the art of rigging aeroplanes which were expected to remain many hours in the air.

Captain R. J. GOODMAN CROUCH, R.A.F., then delivered his lecture.

DISCUSSION.

Lieut.-Colonel STEDMAN said the important thing in the Camel was the length of the longerons carrying the engine-bearers. Captain Crouch had dealt entirely with the tail portion of the fuselage, and not with putting on the engine-plates. That had been a frequent source of trouble, as defective fixing of the engine-plates caused a good deal of vibration, for which the engine got the blame. They were always having complaints about machines vibrating, and he was nearly sure many of them were due to the engine-plates not being put square into the machine. Most of his experience had been gained with the big Handley-Page

machines, and he found that the difficulties encountered with the rigging of a large machine did not exist if the job were tackled manfully. The main thing was to get over the moral troubles connected with machines of that large size. Actually, they were extremely easy to rig. Whilst serving with a squadron they had on one occasion to get out as many machines as possible. One of the machines had been out the night previously, and had the top plane badly damaged. They set to work during the day and changed that plane, took off the box of planes, put on the new plane, re-trued the box of planes, put it in the machine in the hangar, and wheeled out the machine just as the other machines were starting, without looking at the truing up at all. It proved to be perfectly true. That showed that once you had got hold of the job there was no trouble with large machines. He had had a little experience with the Vee type, and he did not anticipate that they would have any trouble with that or with machines two or three times the size. It was simply a question of tackling the job and getting on with it.

Captain THURSTON said he was glad of the opportunity of recording his regard for the work of Captain Crouch, whom he already knew before the war. He had that rare combination, practice with theory, which made him an extremely valuable man. With regard to rigging, he (Captain Thurston) thought that the information to be obtained by living with the machines and rigging them and inspecting them during their service was of such value that every designer should have the opportunity of spending occasional periods with the machines. By that means one found out which parts broke, which parts were unsatisfactory or inconvenient, and which parts took a long time to put together and take apart. By gathering that information together designs could be greatly improved. In one instance he could cite, in a very well-known machine, for some unaccountable reason, the drag wires were always breaking, although they were given a factor very much above that of any other part of the machine. Somebody made the suggestion that if the engine were mounted on rubber blocks the vibration might not be so great on those wires. Rubber blocks were put in, and the result was that those wires could be of less than half the strength of those used previously and they never broke. It was points like those that they wanted brought out. The lecture gave an admirable description of certain types of machines, but did not give all the rigging tips one would like. What they wanted to know was how to rig their machines to get the best speed, efficiency, life, and endurance out of them. Every pilot had had the experience of sending a lovely machine to the riggers for some minor thing and finding after he got it back that it had left all its beauty in the riggers' hands. It was sloppy and heavy on control, and was not the same machine again. On the other hand, one sometimes had the joy of sending a machine which was not nice in the air to the riggers and finding it was a gem when it came back. He had had both experiences, but just now he was suffering from one which had left most of its beauty in the riggers' hands. To facilitate rigging, machines should be constructed in units, to enable as many gangs of men as possible to get on to the various parts. This facilitated production, and also in the field it facilitated replacement of certain damaged parts or correct and rapid re-rigging. The advantage of paying attention to the assembling of machines was shown by the well-known case of two engines of practically the same horse-power, one of which could be taken down and re-erected in 40 man-hours, while the other, with equally skilful workmen, took 400 hours. The same thing applied to other machines. Rigging was not confined to putting together every part of a machine and seeing that it was locked. It also required that exquisite touch or knowledge of the machine whereby the maximum speed and maximum endurance in the air could be obtained. He thought master riggers should be pilots, and have the advantage of taking their machine into the air after they had rigged it, so that they could judge the effect of a little screw here or there. Standardisation was of enormous importance. One had

extreme difficulty when right away from civilisation if parts were not interchangeable. The principle underlying standardisation should be always to give as much tolerance as possible to every part. The tolerances should be laid down by sound practical experience. In some cases the tolerance could be very large, and in others, where such large tolerance could not be allowed, there could be various grades specified—A, B, 1, 2, or whatever it might be. In the early part of the war sufficient nuts and bolts could not be got, and there were also complaints of their lack of interchangeability. It was found to be due to two things: firstly, inspectors were insisting on too good a fit; and secondly, manufacturers were endeavouring to work to the Engineering Standards Committee's requirements, which were rather too fine for war conditions. It was soon put right by multiplying by two or three the requirements of the Engineering Standards Committee, and also by watching inspectors. It was possible to trace the peregrinations of certain inspectors by the nuts and bolts which had been rejected. Some of the manufacturers were horrified when shown on a screen the defects in screws they were producing. The man in the field should be given the maximum chance of putting things together, by giving him the maximum tolerance. As the paper stated, a nut on a screw was not weaker if it was a loose fit. Even with the semblance of a thread they always broke in the screw, and not by pulling the nut over the thread. It was well known that a flying machine could have loose nuts, provided they were amply locked. That principle of tolerance should reach throughout the whole of aircraft construction. The coming of commercial aviation would make rigging and inspection more important than at present. People to whom machines would be taken for repair might shift things which would entirely upset the calculations of the constructor. In the case of a machine which was altered for its elevator controls there was a very sharp angle in the control cable. The fairlead of the control was attached to one of the longerons over the strut originally, but the rigger found it more convenient to attach the fairlead in the middle of one of the bays of the longeron. The effect of placing a big lateral load on the strut could be imagined. Probably the strength of the machine was reduced by nearly a half. Another rigger placed one of the pulleys of the longeron on one of the ribs instead of the spar. These things would multiply when we got commercial aviation, and it was necessary to be quite fair and square about it and point out the vital importance of the structure of the flying machine. It should not be tampered with unless it were submitted to an expert who knew what liberties could be taken with it and what ends must be attained. He thought the future of aircraft lay in metal. With metal construction a large amount of rigging would be done away with. Steel would only deflect about half as much as wood under the same load. Moisture and temperature had nothing like the same effect on metal as on wood. The only type that would last in tropical countries was one of metal construction. We were an engineering nation, and probably knew more about steels than anybody else, and as our future was undoubtedly bound up with aircraft, metal construction was of great importance to us, and he thought if we adopted it it would do away with a good many of the pitfalls which attached to wooden construction.

Mr. BRAMWELL said Captain Thurston apparently held the opinion that the rigger should decide the adjustment of the machine in order that it might do the best performance. In his (Mr. Bramwell's) opinion that was the duty of the designer, helped by the results of the type trials of the machine. The rigger's duty was to turn out the machine exactly in accordance with drawings. If the riggers were allowed to follow out their own individual whims and alter the adjustment of the machines then machines turned out by different squads of riggers would undoubtedly have very different characteristics and would give varying performances. Whereas all machines rigged accurately in accordance with the drawings give precisely the same performance if the engines and propellers were identical and properly trued up.

Captain THURSTON: He remembered a machine in which, after a test, the drag wires were found slack. They had probably tightened them up without noticing that the compression struts were not of sufficient strength. If it had not been spotted there would have been a disaster. It was extremely difficult for riggers to carry out the instructions of the designer. No rule could be applied rigidly as to the tension to be put on the wires. It wanted a man with a certain touch and instinct.

Captain MORRIS said it struck him they had heard very little about rigging. He thought Mr. Bramwell had rather hit the nail on the head when he pointed out that the rigger's job was to keep the machine according to the designer's instructions. Rigging did not consist of a knowledge of the various parts of the machine and what they were made of, but was really the application of geometrical facts. The fuselage may be such that the top longerons are level throughout or may be symmetrical about the centre line, or may have some other property, and that property was shown in diagrams or drawings, and the rigger's job was to get it correct according to the drawings. To do that he had to follow geometrical facts in a certain logical order. He and other people spent about three months trying to true up a fuselage which they did not know much about, and did not get it true after all. The chief reason was that the fuselage was not geometrically accurate. A rigger should have a sort of geometrical sense. Some definite sequence was required, and it was based on geometry. In a fuselage the transverse sections were adjusted until they were at correct rectangles. Captain Crouch said that the internal bracing wires resist torsion, but they were more or less dummies, except the end ones. It would probably be found that only the end wires took the torsion—the side wires, really. The mid-points must be arranged in accordance with some systematic scheme, depending on the shape of the fuselage. The choice of those points was most important. When he started rigging he found diagrams in existence of the B.2.C. For the fourth strut one got a point ¼in. below the mid-point They actually tried to get it ¼in. above, because whoever put down those instructions took a machine incorrectly rigged as a standard machine. This was common in those days. The matter had now been studied from a geometrical point of view, and developments had been pointed out. The method of lining up the points by clamping blocks of wood along the side was a very uncommon method. To give the shape, the whole of the fuselage must be lined up. The actual points must be adjusted geometrically, and the actual tension required on the wires came to the rigger, by sheer experience, by feel. The rigger must understand the effect of pulling up certain wires. If he got the idea that the internal bracing wires resisted torsion he would never get them true. If he knew that twist was eliminated by the side wires, and possibly the top and bottom wires, he would have a better chance of being correct. An undercarriage must be got symmetrical about the vertical centre line, and it was the same with the centre section. The most important thing in regard to the main planes was to get the correct angle of incidence, the correct dihedral, and the correct stagger. In a Sopwith Camel the lower planes were at a dihedral of 5 degrees, the top plane was flat throughout and the stagger was 18in. When the first machine was erected they got horrible results in trying to get that stagger 18in. throughout. The lower wings fell back towards the wing tips, but not the top ones. An A.I.D. inspector found that the difference was really 5/16in. By trying to get it 18in. there was great trouble. If riggers had been taught geometry in connection with their rigging they would have easily found that mistake. In making a plane true the only wires that allow adequate adjustment to get the dihedral correct were the front and rear landing wires. These supported the plane on the ground. On some machines, like the Bristol Fighter, in which the dihedral might be the same front and rear, you got it by both. Incidence was merely the relation between the rear and the front spar. Having fixed the front

spar, the rear landing wire came in for lowering or raising the rear spar, and finally the plane was braced up to preserve the stagger. If more incidence were wanted the rear landing wire was let out, and if less were required it was simply pulled up. When the dihedral and incidence were secured the stagger would probably come out accurate. If not, a slight adjustment could be made. The rigger's job was fundamentally geometrical.

Mr. R. RODGER: Captain Morris was very emphatic about the part which geometry should play in rigging, and there is no doubt whatever that every rigger worthy of the name should possess a sound knowledge of the basic principles underlying the science of geometry. But in my opinion this alone is insufficient. I think that the master rigger, or ganger as he is known in the erecting shop, should, in addition to geometry, possess some knowledge of the theory of structures as applied to pin-jointed frames. One speaker during the discussion touched upon the subject when he mentioned that the aeroplane was a redundant structure, and it is this point which I wish to emphasise.

A knowledge of the elementary theoretical principles of framed structures would be of the utmost possible advantage to any master rigger as he would be able to define at a glance which members were redundant. These members could then be removed right away from the scene of erection altogether, thus facilitating erection by rendering easier the task of the semi-skilled man and by lessening the number of possible errors.

The basis of the perfect plane frame is the triangle which has three members and three joints. For every additional joint two more members will be required in building up a more complex perfect frame which is always divisible up into triangles, hence for four joints the number of members is $3+2$, for five joints $3+4$, and for n joints $3+2\,(n-3)$, or $2n-3$. This criterion serves to show the master rigger on inspection whether a plane frame is perfect, deficient, or redundant, and with but an elementary knowledge of the theory of structures he will be able to locate the unnecessary members of the frame and remove same.

Captain G. T. R. HILL said the whole essence of the thing was that the aeroplane was a redundant structure. There were more wires in it than were required to make it safe. There were a certain number that could be tightened up to get the machine correct, and others could be left slack and finally tightened up just so that they did not alter the rigging. The author said that one should adjust the dihedral and then the incidence and leave the stagger till the last, but the stagger would have to be adjusted. If measurements were taken from the tips of the wings to the rudder and did not come equal, the fuselage must be checked over again for straightness. There was nothing else to be done. Wires could not be tightened up without distorting the structure. If a machine were rigged with no wash-in or wash-out and correctly rigged as measured with spirit-levels and it glided with one wing down, it might be due to the fabric having a different degree of tightness or being lighter fabric on one side. The fact that a machine flew in a certain manner was not entirely due to the geometrical arrangement of the wings. Some riggers thought there was some magic in the joystick being vertical when the machine was in a horizontal line with the tail, and the fact that that was a fallacy should be drilled into them by the D.I. Dept. text-books. When he was in a training squadron they had D.H.2s, and there were no drawings for erecting them. The mechanics carried in their heads the incidence, say "Three B's," and so on. When some F.E.8s came along, with their wings on lorries, there were no instructions as to erecting them. That was the sort of information supplied to squadrons in these days. They discussed whether the dihedral angle was 35 or 45 degrees.

Mr. E. C. P. ALLARDYCE: In the early part of his lecture, Captain Crouch, referring to the drift and flying wires, said: "Soft iron wire should be used for locking, sticky tape as a covering being deprecated."

The use of locking wire on internal cross-bracing wire was distinctly prohibited by the Technical Department as far back as last August (see T.D.I. 543 8/8/18), and instructions given for the binding of one wire with tape at the point of intersection, in order to prevent rubbing. At my own station I personally gave instructions for the use of electricians'-adhesive tape in preference to ordinary glued tape, as being more likely to remain in its proper position on the wire.

The lecturer further said that sticky tape should not be used, as it would hide rust and other defects in the wire, whereas waxed string would be perfectly satisfactory. I consider that waxed string is quite as likely to hide defects as adhesive tape; and further, as in the case of ordinary glued tape, it is liable to slip along the wire, and would therefore not prevent chafing. *Quod erat faciendum.*

I quite agree with the lecturer in deprecating the use of tape or anything of the sort that is likely to hide defects in material, but it is absolutely necessary to prevent the chafing of wires if we are to save our pilots from innumerable accidents. A method which I should like to suggest of overcoming the difficulty, and one which, as far as I am aware, has not been adopted by any designer up to the present time, is that of fixing the drift plates slightly diagonally on to the spars, instead of longitudinally; by this means we would have the drift and flying wire in each bay in separate planes, instead of in the same plane as at present, and the wires would be at least ½in. to 1in. apart at the point of intersection, thereby preventing any possibility of chafing and obviating the necessity of locking or protection.

If this system were adopted the drift wire plates should each be secured to the spar by two bolts, as in the H.P.°/400 Aileron, instead of by one bolt, as in the main plane of the D.H.6, to prevent the possibility of swivelling on the bolt. When, however, the lugs for the bracing wire are an integral part of some other fitting, they could be staggered to obtain the same effect.

In the Handley-Page, in the top centre section, instead of wires they had swage rods, secured by being locked with a piece of 12 or 14-gauge wire. It would be more satisfactory if those swage rods were locked by means of a split washer and a couple of nuts. The inspection hole in the cover enabled the nuts to be loosened or tightened, saving the large amount of trouble incurred in altering the tension of the swage rods, which involved taking off the locking wire and putting it on again.

Captain Crouch spoke of the enormous amount of labour and expense caused by having the undercarriage socket, the bottom longeron socket, and the engine bulkhead plate built in one piece, as in the event of an accident to the undercarriage damaging the socket it necessitates considerable trouble and expense in replacing the defective part. I should like to suggest, as an improvement on present methods of construction, that all lugs for lift and weight cables, and all sockets for interplane struts—in fact all fittings which apply more to rigging than to construction—should be constructed on flat sole plates to be bolted on to the planes after covering and doping, as is, I think, the case with the Avro. The present method of fixing these fittings to the spars and allowing them to protrude through the fabric is certainly not a businesslike proposition, as to replace any defective or damaged part necessitates ripping open the fabric at that point, and often entirely destroying the whole fabric of a wing.

Motor-cars of the present day are built in such a way that any chauffeur of average intelligence can do his own running repairs with as little delay as possible, and I consider that aeroplanes should be built so that the pilot (or rigger, if he has one aboard) will be able to follow this example. In the case of a forced landing, due to a broken lug or socket, the passengers would naturally

wish the repair to be carried out as expeditiously as possible, so as to proceed on their journey, instead of having to wait for a new wing section to reach them, more especially if the landing were to take place in the heart of Central Africa or on the Khalihari Desert 50 miles from the nearest inhabited spot.

There was a better method of truing up a fuselage than by clamping blocks of wood to the vertical struts. A careless or inexperienced man might get the block on one side higher than the other, or one in front higher or lower than the one at the rear, in which case his truing up would be false. The method adopted by Haviland was rather better, and more foolproof. They got their trestles dead horizontal and then raised the fuselage on the lower longerons on those trestles, and placed straight edges at various points resting on the two top longerons, and in that manner trued up the fuselage. It prevented winding, and also had the advantage that after the construction was covered with three-ply or fabric its truth could be again tested.

Speaking of turnbuckles, Captain Crouch recommends that "the threads should disappear from view" in order that safety may be assured. I cannot agree with him on this point, and have always made a hard and fast rule that from one to three threads, but certainly not more than three, should always be visible after truing up is complete. This, in a serviceable turnbuckle, should leave quite sufficient threads engaged in the barrel for a full margin of safety. The flying and drift wires of a wing are always bound to become somewhat slack after flattening out from a nose-dive or after repeated landings, and if the threads are home in the barrel of the turnbuckle there may not be sufficient take up left; consequently new wires must invariably be fitted.

Considerable mention was made of the Handley-Page°/400, which is a machine that I have always considered as the coming vehicle of aerial commercial transport. If I may be permitted to do so without being considered presumptuous for criticising the design, I would suggest that if there is a fault it lies in the intricate manner in which the metal fittings are built up. I have always considered welding, brazing, etc., as perfectly satisfactory in individual cases where naturally the utmost care is taken, but where the joining of various vital parts becomes routine there is always a grave risk of a defective fitting being built into the machine by accident. Owing to the size of the fittings and the past shortage of steel and other metals, the present method has probably been unavoidable, but it is to be hoped that in the near future these parts will be made from the solid with the necessary lightening holes cut in them.

Mr. CHARLES SOLLEY said he wished to mention one or two points from the workman's point of view. Nails caused black rot in the wood. That had been overcome largely by using dope-resisting paint. Timber was sometimes used before it was thoroughly dry, and when it shrunk it resulted in fittings being loose. Struts should be well fitted in their sockets, otherwise the machine could not be trued up. The standard method of locking on turnbuckles was to take the wire through the hole in the turnbuckle, bring it up, and finish off at each end. He thought that was wrong. The turn should be made with the locking wire round the turnbuckle in the opposite direction to that in which the turnbuckle was turned. If the angles on lugs were not exactly true the lug would straighten out and the bracing become slack.

If a machine is correct to drawing in every detail and the drawings are correct, then final truing up should consist of registering that correctness only, and where any adjustments are necessary then the cause should be found and adjusted. The most essential quality to the construction is excessive carefulness from the very beginning, both in the workmanship and the selection of material, for it is by that only that the true machine can be made.

The first point is in the detail woodwork and metal shops, where the troubles

commence. In regard to spars, a frequent cause of trouble is in shrinkage caused by insufficiently seasoned timber. This trouble is found out by fittings being found to be loose, also by splits developing, caused by the timber shrinking over bolts. These splits are usually noticed at the end of solid or laminated spars. This is not so bad, as they can be detected here, but disaster may be caused if they occur in the blocks inside built-up spars, as here they are hidden by the cover boards. There is a tendency for timber to cast or bow on drying. Unknown faults that develop in a machine may be traced to this cause, even though at the time of assembly the offending spars or struts may have been perfect. Another very serious fault may develop in a machine, that of an aileron or elevator grinding or pulling heavy on the control or even refusing to act. This may be caused by the spar bowing and throwing the hinges out of centre. Many modifications could be made in boxing out spars, struts, etc., for lightness that would be an advantage both in respect to strength and lightness. While on the subject of timber, an enemy to the life of a machine is damp. This attacks a machine in many ways. First, if unseasoned timber is used, it sets up rust on all nails or bolts that it may come in contact with. This may be observed when a machine is in to be repaired; when the fabric is stripped from the planes all nails are surrounded by a long streak of black rot in the wood caused by the action of the iron on the damp spruce. This is now countered by means of dope-resisting paint, but if the timber is damp the paint only covers the evil. Damp is also the enemy of the glue used. This is also countered by varnish, but the same rule applies as before. Where swaged rods or internal bracing pass through boxing of any sort a piece of fabric should be stuck over the hole tight round the swaged rod to stop damp entering. The inside of all boxing or built-up spars is varnished; but you cannot varnish the glue, and the damp may find an entry here. It is a well-known fact that the glue squeezed inside the boxing will absorb any moisture that may find entry. Of course, these faults may all be overcome, and if they are timber is an ideal material for the building of aeroplanes, and with the best of timber, well seasoned, good workmanship, and a thorough attention to small details, the results are excellent. Extra strength may be obtained by good workmanship, and by the combination of the perfect joints both in metal and wood, and by the careful selection of materials every atom of fabric, metal, or wood takes its full share of strain. Untidy welding, although sound, can wreck a machine. Take, for example, a strut socket with an unsightly blob of metal left in; this would, if not noticed, stop a strut from finding its proper bearing. The mechanic fitting the strut would, under the impression that his strut was home, perhaps cut the other end short, and the strut rigged in the machine, the compression put on by bracing would slowly force the strut home, and the result would be extra weight put on the other struts, which would take more of the strain than what they were designed for, with the result that the machine, perhaps having one or two awkward landings or gusty weather, the other struts develop faults also, with disastrous results. For this reason selection of timber in boxed struts should be of the same texture, as a hard and soft half strut if combined would throw extra strain on the hard half and probably start the joint opening. In selection of timber a good guide for spruce is to examine the end of a log when cross cut. It will be found that the heart of the tree has very coarse wood by examining the rings, which may be even three rings to the inch, then get closer as the tree grows until a point is reached where the immature wood commences towards the outside of the tree, the best wood being where the rings are closest together, the reason being that the tree grows fast and coarse when young in virgin soil and is glutted with organic matter. After many years, when the tree starts to exhaust the soil, Nature's unfailing rule, "The survival of the fittest," comes into play, and the hard, wiry fibres which are to combat wind and storms through future years are formed. This is the true wood, and the lower portion of the trunk is the hardest, heaviest, and toughest, as it has to stand the strain of the big spreading upper part with its boughs and leaves, which offer

such an obstacle to the winds. There are other faults in workmanship which cause a machine to require such a large safety factor. One, though it may seem small, is the pulling in of fittings by tightening up bolts too much. The effect of this is to compress the fibres inside the fittings, and if such a piece of wood be examined under a microscope it will be found that the albumen joining the fibrous tubes is split and the tubes themselves compressed, and if a shock is suddenly given it is at this point the rupture takes place. Taping under fittings, though not usually resorted to, is worth considering. Another small matter with sometimes big results is wiring lugs not being true in line with the angle of the bracing, the result being, as they straighten out after the machine has passed out and takes the air, the machine is out of truth when flown. Also note should be taken to see that the holes in wiring lugs are rounded, sharp edges shearing the bracing when compression takes place. Other little snags are internal drift bracing cutting rib braces. One or two braces does not seem much, but there should be nothing unnecessary in an aeroplane and every brace is wanted. Another case of faulty workmanship is in bending piano wire through the holes of bracing lugs previous to putting ferrules on; this should be bent once only; any subsequent bending would probably develop flaws which might break at any time when flying. Washers under bolt heads and nuts should not be pulled into the wood. A fork or eye bolt is a faulty fitting to hinge an elevator on if it is possible to turn round, and the happy medium must be found between the bolt pulling the washer into the wood and being loose enough to turn. Another offence is boring holes from each side of a spar so that they meet in the middle at an angle. In the vernacular of the shop, "rats' holes," there is no way of detecting this when the bolt is home, but it usually results in the bolt pulling through the wood diagonally when the strain is applied. A great mistake in designing is to have the bracing rods at such an acute angle to the struts that the struts have to be cut away to allow the spanner to be used—a fault of a well-known machine. Designers have a great weakness to design a machine and then add attachments afterwards without taking into consideration the weakening of the original structure by fixing of auxiliary attachments. Amongst minor defects is that of the knotting of the fabric through the planes cutting through the flanges of the ribs when pulled tight. Another weakness is having holes for bolts, etc., in line with the washed-out end of a spar without having tie plates round the spar, an example which was once proved by a slight jar in the shop, but which might have happened in the air. It would be as well to mention that draining holes in planes, etc., should be at the inner edge of the trailing edge, an example being that in some cases trailing edges are bound round with tape to attach the fabric to. The moisture is around this tape, and the trailing edge, being continually in a wet condition, rusts very badly. In cases like this a good remedy is plenty of dope-resisting paint soaked into the tape. The first coat of dope should be well worked into the fabric before applying subsequent coats.

Finally there are one or two little tips like a touch of solder on clips for ribs at round ends of metal trailing edges, carefully bending over split-pin ends. Overstraining one wire to pull a bay square when the fault lies somewhere else to be avoided, and cutting all fuselage strut ends off at correct angles so that they bed solid on longerons. Care also in the foundry to see that the pattern does not slur when being drawn from the sand and cause a casting to be thin in one place and thick in another, and also that the solid parts of struts, etc., when boxed out, are exactly opposite to one another before glueing up and varnished inside. A faulty strut boxing may be a brave airman's grave. And such little things as the spindle cutter rupturing and starting splits in faulty machining should be looked for. In a good, clean job any concealed fault is brought to light, and the greatest curse of timber, the thunder shake, should be looked for at all times; and, in conclusion, strict observation that all parts of the machine are weatherproof by application of paint dope, varnish or grease, easy free-running controls without slackness, and a confident airman will make record flights on a perfect machine.

Captain E. G. WALKER: One feature may be noted in connection with the paper which though not a matter of rigging pure and simple is one upon which the safety of the machine to a very great measure depends.

On page 2 it is stated that pulleys, and presumably also fairleads, for control cables should have a diameter of about 20 times that of the cable. So far as the actual working strength of the cable is concerned, this allowance is certainly not over generous. The important part which the diameter of the pulley plays in the life of a stranded wire cord passing round it does not appear to be fully realised, and it is probable that in a good many cases the actual factor of safety in such small cords is very much less than is reckoned upon. For reasons, presumably, of compactness and saving of weight, designers are often content to cut down the diameters of pulleys and fairleads to a dangerous point, and aeronautical constructors are often content to subject small stranded cords to conditions which if proportionately applied to large wire ropes would scare any responsible engineer who happened to be in charge of their maintenance. The figure given in the paper for the minimum diameter of the pulley, namely, 20 diameters of the cord, whilst possibly representative of average practice, is considered by the writer to be low. The following table gives some results taken at random from experiments made on the subject:—

Diameter of Cord. ins.	Diameter of Pulley. ins.	Ratio of Diameters.	Ultimate load for unlimited life.	Static breaking load. lbs.	Ratio of breaking loads.
.115	6	52.5	300	1,120	.268
	2	17.4	40		.036
	1	8.7	12		.012
.075	3	39	62	560	.111
	1	13	18		.032

In the case of the larger cord the ultimate load for unlimited life given in the table is the maximum load in which the cord will stand 200,000 reversals of load in the case of the larger and 100,000 in the case of the smaller cord. The figures given are not to be considered as laying down any definite law, but rather as random experimental results, and they show very decidedly the deleterious effect of turning small cords around small-diameter pulleys. It will be seen that with a pulley diameter 50 times the diameter of the cord the strength is reduced by 75 per cent., and the effect of using very small diameters is almost to nullify the value of ultimate strength as obtained from a plain tension test altogether, as the breaking load of the cable tends to become almost independent of its size. The same effect has been noted in the case of hemp cordage.

The importance of large pulley diameters cannot be too strongly insisted upon, and it is thought that the majority of failures of small cords, both in wire and hemp, when passing over pulleys are due to neglecting to provide adequate sizes of pulleys.

Mr. W. E. BENBOW: Captain Crouch during his lecture insisted on the necessity for standardisation of the methods of rigging; his remark applies with especial force to the rigging of fuselages.

There is a tendency amongst fuselage riggers to brace the fuselages as tight as they can, under the mistaken idea that the structures should be rigid. This tendency should be combated by standardising the tensions of the bracing wires. It is obvious that a fuselage may be geometrically true with its bracing wires very much over-tightened; such a fuselage is dangerous for several reasons. For instance, on coming out of a loop there is a tendency for the fuselage to bend in a vertical direction; if the structure is "live" and supple the strain is taken gradually and no harm results, while if the structure is rigid it receives a sudden shock, which may have disastrous consequences.

Even the "static" stresses which are caused by over-taut wires, and which would exist whether the machine was in use or not, may result in crushed or bowed struts or broken turnbuckles. (Turnbuckles have been known to break on the fuselages when samples from the same batch have, on test, only broken at 20 per cent. above the rated tensile strength.)

All the evil results of over-taut wires might be avoided by the use of a tensionmeter. There are several of these instruments which can be used on wires in position without damage to the wires, and I therefore suggest:—

(1) That the tensions of the wires of any type of machine should be determined experimentally and limits for the tensions put on the rigging diagrams.

(2) That the fuselage erectors should have the use of an approved type of tensionmeter to test the wires after the fuselage is trued up.

(3) That the A.I.D. Stations should have tensionmeters to test, say, one fuselage in three or five.

As to the experimental determination of the correct tensions for bracing wires, no doubt some simple method could be devised. For instance, a machine which has been accepted by, say, six pilots (each of whom has had his pet setting of the controls for the test), as a "live" machine should have the tensions recorded and thus a practical standard could be obtained; by taking the average of several machines a series of limits could be made and instructions issued to constructors that bracing wires should have tensions between xlbs. and (x + a)lbs.

Thus a step more in the direction of standardisation would be taken.

Captain CROUCH, in reply, thanked all members who had been good enough to join in the discussion.

With reference to the importance paid to construction in a lecture on "Rigging," he considered that, although they were two different subjects, mention of both was necessary when dealing with either.

The form of construction employed in the "Panther" fuselage, for instance, was such that the parts were "jig-trued" during erection. "Truing up" after construction was not only unnecessary; it was impossible.

Moreover, in his opinion much time and labour could be saved by riggers possessing constructional knowledge.

One speaker had mentioned that three months had been spent in trying to get a fuselage true. He ventured to suggest that this period might have been considerably shortened if more importance had been paid to the possibility of errors in construction.

Captain Thurston had rightly said that the information to be obtained by living with machines, and rigging and inspecting them during their service was such that every designer should have the opportunity of doing so for occasional periods. By this means he (the designer) would be enabled to design components which were not only capable of standardised production, but which would allow in addition every facility in erecting and dismantling.

Faults in erection, such as Captain Thurston had mentioned, could only be eliminated by employing really skilled men and having a thorough system of inspection.

The actual work of the rigger, as Mr. Bramwell had pointed out, was to turn out machines exactly to drawings, but this in itself was not all, for at the present stage of development minor adjustments were often found necessary after test flights had been made in order to ensure absolute truth in the air.

Good test pilots were essential for trial flights as otherwise there was difficulty in communicating ideas of the faults of machines to the riggers.

It was obvious that no one could be expected to make the necessary adjust-

ments to a machine if the only information given by the pilot was that "she seemed funny in the air."

A few years ago every flight on a machine necessitated work in the shops or hangars, re-truing and adjusting the machine for its next flight. That period had now been passed and it was quite conceivable that in the near future jigs would play such an important part in erecting that no subsequent "truing up" would be necessary.

With regard to fuselage internal cross bracing wires, these, except in one bay, were redundant, but the whole structure was kept far more rigid than it would be were they omitted.

The point raised by Mr. Allardyce concerning the use of soft iron wire for locking purposes was, he thought, based on a slight misunderstanding..

He (Mr. Allardyce) was evidently under the impression that soft iron wire had been suggested for binding cross wires, whereas it really referred to turnbuckles. Chafing of cross bracing wires could be efficiently prevented by the use of waxed cord or sticky tape on one of the wires, but the danger of hiding defects was considerable. The practice of locking turnbuckles with soft iron wire, however, was sound, and in fact in accordance with Air Ministry Instructions (see T.D.I. No. 505), and he quite agreed with Mr. Solley that the turn should be made with the locking wire round the turnbuckle in the opposite direction to the thread. This method had given complete satisfaction at active service stations during the war.

The type of turnbuckle in wh'ch the thread was of such a length as to ensure a good factor of safety when only the machined shank was visible was found to give a good margin for further adjustment, this, of course, being dependent on the length of barrel. The design was originated in order to simplify supervision, for inspectors could at once tell how many threads were engaged by a glance at the strainer.

He did not consider it advisable to design fittings necessitating welding if the welded parts were likely to incur strain under vibration.

The lecturer quite agreed with Captain Walker on the important part played by the pulley diameter in the life of cable. It was in view of this that he had mentioned the point as there might be the danger of a damaged pulley being replaced by one of smaller diameter, if proper care were not exercised. The rough figure of "20 times the diameter of cable" should be taken as a minimum.

The question of tension in bracing wires raised by Mr. Benbow was of considerable interest.

The use of the tautness or tensionmeters was not at present general as men with experience could tell by hand whether the requisite tension was in the wires.

The lecturer concluded his remarks by thanking the Chairman for his kindness and expressing his appreciation of the help given him by Messrs. Sopwiths, Messrs. Parnalls, and Messrs. Handley Page, and the Publications Section of the Air Ministry, whose valuable aid had greatly facilitated the illustrating of his remarks.

Votes of thanks were accorded to the Lecturer, on the motion of the CHAIRMAN, and to the Chairman on the motion of Major-General R. M. RUCK.

ABSTRACTS.

Martin Twin-Engined Bomber.

The general characteristics making this machine stand out from others of its type are its good flying qualities and high efficiency. It is claimed that it is most comfortable to pilot, answering all controls readily with full load and either one or both engines running. With one engine it is easy to climb, to turn, and to land comfortably in a small field. It recovers easily from a tail spin and is very stable, pursuing a steady course for a long period with all controls released, and yet exhibiting no stiffness or dangerous tendencies in gusts.

Its all-round efficiency has been proved in trials, an official speed of 118.5 m.p.h. at the ground with full bombing load having been attained. This has been improved on since. Also with full bombing load it has climbed 10,000 ft. in 15 minutes and reached a service ceiling of 16,000 to 17,000 feet.

As a military machine it is built to fulfil the requirements of—

1. Night bomber. Three Lewis guns, 1,500 lbs. bombs, 1,000 rounds of ammunition, with fuel for half an hour on the ground and six hours' full power at 15,000 ft.
2. Day bomber. Five Lewis guns, 1,000 lbs. bombs.
3. Photography machine. Five Lewis guns and two cameras.
4. Gun machine. Five Lewis guns and a semi-flexible 37 mm. gun.

It is easily adaptable for commercial uses as—

1. Mail machine. A ton can be carried with comfort.
2. Passenger machine. Twelve passengers, in addition to pilot and mechanics, can be carried for 600 miles (non-stop).
3. Aerial map and survey work.

The wing truss is conventional outside each of the engines through the body, the system being of streamlined steel tube. The members are arranged with the view to ease of removal of engine, rigidity and simplicity; hence low weight and resistance. The wing spars are of the usual spruce eye-beam type, but the wing ribs are of a novel type developed experimentally. They have a factor of safety of eight. The wing fittings are all designed to give a factor of safety in excess of six.

The body is the most interesting part in many respects. The pilot is placed on the right-hand side, well up, with a good range of vision, and there is a passage so that the front gunner can go aft to handle the rear lower gun. Behind the pilot are three main fuel tanks, and under the seat a hand-wheel is placed for operating the adjustable stabiliser. The firing platform for the rear gun is situated near the rear spar. The lower gun commands a large field of fire to the rear, below, and to both sides. The body in most other features is a combination of two types, the wire strut truss and the veneer-plated wood truss. The tail skid is braced entirely by the internal body structures at the rear panel points, it is universally pivoted and sprung inside the body to receive landing shocks.

The two 12-cylinder Liberty engines mounted in light girder boxes of veneer, rest on brackets on the four main wing struts, so that engines, radiators, airscrews, and nacelles can be removed intact. Nose radiators are mounted in a very satisfactory manner, and equipped with shutters for regulating temperature. There are cushions of rubber between it and the mountings to absorb shock.

The under-carriage is composed of four 800 x 150 mm. wheels, the flexibility of the mounting gear absorbing all kinds of shocks satisfactorily. The gear is simple, light, and of low resistance.

A single wheel and foot bar control is provided in the pilot's cockpit, with the usual weakness eliminated. There are four equal unbalanced ailerons.

The tail surfaces are of steel and wood. The stabiliser is adjustable from the pilot's seat and has a range of angle of three degrees on both sides of the neutral. The elevator is of one piece, and the two balanced rudders work in synchronism.

In addition to the three fuel tanks in the body, there are two gravity tanks mounted on the upper wing above each engine, all securely braced by many internal bulkheads. All valves are easily controlled by the pilot, and an efficient hand-pump is provided to fill the gravity tanks or engine should the two air driven pumps fail.

Dimensions, etc.

Upper planes (including ailerons): 550 sq. ft. (span 71 ft. 5 in.).
Lower planes (including ailerons): 520 sq. ft. (chord 7 ft. 10 in.).
Four ailerons (each): 32.5 sq. ft. (gap 8 ft. 6 in.).
Two vertical fins (each): 8.8 sq. ft.
Stabiliser (normal setting — 2°): 62.25 sq. ft.
Elevator: 43.20 sq. ft.
Two rudders (each): 16.50 sq. ft.
Overall length: 46 ft.
Overall height: 14 ft. 7 in.
Incidence of wings with airscrew axis: 2°.

(D. W. Douglas, "Aviation," Jan., 1919.)

Future of the Helium Airship.

The article discusses the possibilities of commercial uses for the airship, in particular with helium used as a substitute for hydrogen. Helium is an inert non-inflammable gas having 92 per cent. of the lifting power of hydrogen.

Hitherto the difficulty has been that of production and expense, the largest amount in any container previous to 1918 being 5 cubic feet, the cost of manufacture being anything between 1,500 and 6,000 dollars. A process has, however, been discovered, thanks to Government subsidies, etc., of which an account is given, that will enable the pure gas to be produced at the cost of approximately 100 dollars per 1,000 cubic feet. Accordingly it is claimed that the prospects are considerable.

The importance of the discovery is apparent on consideration of the non-inflammable properties of the gas, all of the danger associated with hydrogen being eliminated. It is also stated that the leakage of helium through gold beaters skin is less than that of hydrogen. (L. d'Orcy, "Aviation," Jan. 1, 1919.)

Balancing Aeroplane Propellers.

A perfectly balanced propeller has its centre of gravity exactly on the centre line of the propeller shaft on which it rotates. In practice, although the propellers are made out of wood, as homogeneous as possible, and the two blades as nearly identical as can be attained, one blade is invariably heavier than the other.

The balancing of the propeller to make the centre of gravity of the propeller coincide with the centre of gravity of the propeller shaft can be done either statically or dynamically. The method of procedure for the static balance only requires simple appliances, but is very tedious and slow to carry out.

The dynamic balance can be done much more quickly, but it requires a rather complicated and expensive balancing machine, and in consequence the static method is in more general use than the dynamic.

The author proceeds to explain a dynamical balancing process built up on the same principles as the statical method, which is such that while the results are

as exact as those obtained statically, it has the great advantage of being rapid in execution. An additional point is that the apparatus required is as simple as that for the static test.

The propeller is fitted to the horizontal testing axle, which rotates on ball or roller bearings so that it is as frictionless as possible. The bearings are rigidly mounted sufficiently high above the floor level to allow the propeller to rotate freely. If the propeller be left to itself it will, after several vibrations, come to rest with the centre of gravity in its lowest position. The weight which must be added to obtain the true balance can be obtained mathematically by following out a simple system of calculation given by the author, the data for which is gained from the results obtained by fixing known weights both above and below the propeller centre, at different given distances.

The article is concluded by some hints on errors to be avoided in making the tests, such as ensuring that the testing axle has no bend in it through the weight of the propeller, that the propeller does not slip on the axle, and that the bearings on which it runs are perfectly rigid. (Baudisch, "Der Motorwagen," Dec. 20, 1918.)

Aircraft Service for Berlin.

The firm of Schütte-Lanz has been granted permission to establish a service for passengers and goods by aircraft between Berlin and all parts of Germany. Until the traffic develops the charges include the cost of the return journey empty. ("Zeitung des Vereins Deutscher Eisenbahnverwaltungen," Dec. 11, 1918.)

Gallaudet D.4 Light Bomber Seaplane.

This machine has been adopted by the U.S. Navy Department for light bombing operations. It is a biplane having a fuselage of streamline form, large central float (no tail float), and two wing floats.

The unique feature of the machine is that the single airscrew, which is of the "pusher" type, is employed in combination with an enclosed fuselage of the tractor type. The fuselage is of circular section at the forward end, where the gunner's cockpit is located. A flexible scarf ring for mounting twin Lewis guns is placed around the cockpit. Immediately behind the gunner's cockpit is the pilot's cockpit, which is just forward of the main planes.

The engine, a 400 h.p. Liberty "Twelve," is located aft of the pilot and between the planes. It drives a ring, surrounding the fuselage, to which the four blades of the airscrew are attached.

The planes have no dihedral angle, but extra vertical fin area is obtained by partially covering in the space between the outer front and rear interplane struts. The planes are similar in plan with ailerons on upper plane only. There is a moderate stagger and pronounced sweep back. The general specifications of the machine are as follow:—

Span	46 ft. 6 in.
Chord, both planes	7 ft.
Gap between planes	7 ft.
Total wing area	612 sq. ft.
Weight empty	3,800 lbs.
Weight of useful load	1,600 ,,
Weight fully loaded	5,400 ,,
Maximum speed	126 m.p.h.
Slowest landing speed	42.6 m.p.h.
Climb in two minutes	2,100 ft.
Flying radius at full power	3 hours.

The useful load is made up of the following:—

Water	115 lbs.
Pilot and observer	350 ,,
Fuel and oil	650 ,,
Ordnance	95 ,,
Bombs	390 ,,
Total	1,600 lbs.

The centre section of the upper plane contains a 38-gallon fuel tank with a supply pipe running straight down to the engine below it. A 75-gallon fuel tank is placed in the main float below the centre of gravity. The fuel system employs twin windmill pumps with overflow return.

Two radiators are located in the centre sections on either side of the gravity fuel tank. They are set into and conform to the outline of the wing section.

The framework of the fuselage is of steel tubing. The main float, which has one step, is of mahogany and has 16 watertight compartments. The two wing tip floats each have five compartments.

Throughout the entire construction, fittings are of aluminium bronze, which makes them proof against corrosion. Struts and spars are of steel tubing. ("Aerial Age Weekly," December 30, 1918.)

Martin K.111 Single Seater.

This machine designed as an altitude fighter is equipped with oxygen tanks behind the pilot's seat, and has full provision for electrically heating the pilot's clothing. The seat is so located that excellent vision is obtained. The machine can light down upon and start from a country road, while on one gallon of gasoline it can travel 22 miles. For the transport of mail and small parcels in rural delivery, it is extremely economical. The cost of maintenance and operation is estimated as only slightly greater than for a Ford automobile, while the work is done ten times faster. The main planes are unstaggered, there is no dihedral, the aerofoil section being that known as Openstein I. At 40 m.p.h. this wing section has an L/D ratio of 22.

The principal dimensions and weights are given in the following table:—

Dimensions.	ft.	in.
Span, upper plane (without ailerons)	15	0
Span, lower plane	17	$11\frac{1}{4}$
Chord, both planes	3	6
Gap between planes	4	6
Length overall	13	$3\frac{1}{2}$
Height overall	7	$4\frac{1}{4}$

Weights.	lbs.
Engine	85.50
Wings	60.75
Fuselage, complete	106.50
Propeller and hub	13.62
Total weight	350.00

The fuselage is designed to stand a load of 105 lbs. per sq. ft. of horizontal tail. Rubber covering between stabiliser and elevators closes the gap between the surfaces. There is no fin and the rudder which contains the tail skid is provided with balanced areas both above and below the fuselage.

Engine Group.—The power plant consists of an air-cooled two-cylinder opposed "Gnat" A.B.C. engine, developing 45 h.p. at 1,950 r.p.m.

Fuel consumption, 0.56 lbs. per h.p. per hour; weight, 50.4 lbs. Oil consumption, 0.017 lbs. per h.p. per hour; weight, 1.55 lbs.

The fuel tank is located in the upper main plane above the fuselage. It has a capacity of 9.03 gallons, sufficient for a flight of two hours.

Its performance and endurance is given as under:—

Altitude (ft.).	Time (mins.).	Speed (m.p.h.).
0	0	135
5,000	3	113
10,000	6	112
15,000	11	111
20,000	18	108
25,000	28	97

(With 60 h.p., 100 lbs. engine—speed 145 m.p.h. at 10,000 ft.)

Endurance at 10,000 ft.:—

At full power ... ... 222 miles.
At minimum power ... ... 216 miles.

("Aerial Age Weekly," December 23, 1919.)

EDUCATIONAL.

Lectures on Aeronautics during the Summer Session, 1918.

The distribution of lectures on Aeronautics at the various colleges is very similar to that of the Winter Session. There is a slight increase in number, although a few lecturers have retired. The following subjects have been included in the syllabus: Meteorology, which is so important for all airmen. Aero- and Hydrodynamics, which occupy such a large place in the theory of aircraft, and Wireless Telegraphy, which is being increasingly used on aircraft. In taking up these subjects, it was stipulated that they should also be treated in these lectures in their relations to aeronautics, even when this is not mentioned in the title. When, for example, Professor Mosler (Brunswick) lectures on wireless telegraphy, stations on airships and aeroplanes will also be included.

COLLEGE.	NAME OF LECTURER.	TITLE OF LECTURE.	NO. OF HOURS.
Berlin ...	Hellmann ...	Theoretical Meteorology	1
		Meteorological Conference	1
	Hergesell ...	An investigation of air in connection with science and aviation	2
	Less	Practical science of weather and climatic conditions	1
		On the atmospheric conditions then present	1
	Marcuse ...	Geography, taking bearings in travelling by land, sea or air with demonstrations	1½
	Neesen ...	Atmospheric electricity, lightning conductors	2
	Seeliger ...	Rudiments of hydrodynamics	1
Breslau ...	Schaefer ...	Mechanics of space (electricity, hydrodynamics)	5
		Demonstrations in the mechanics of space	1½
Giesien ...	Fromme ...	Meteorology	1
Göttingen ...	Wiechert ...	Meteorology	4
Heidelberg ...	Wolf ...	Elements of meteorology	2
Munich ...	Ewald ...	General view of mechanics, including hydrodynamics, etc.	3
	Schmauss ...	General meteorology and science of climatic conditions	4

COLLEGE.	NAME OF LECTURER.	TITLE OF LECTURE.	NO. OF HOURS.
Prague ...	Spitaler ...	Weather forecasts	2
		Practical demonstrations in weather forecasting	1
Vienna ...	Exner ...	Meteorology and science of climatic conditions	3
	Schmidt ...	Selection from the dynamics of the air and water enveloping the earth ...	1
Basle ...	Knapp ...	Meteorology	1
Berne ...	Luterbacher ...	Meteorology	1
	B. TECHNICAL COLLEGES.		
Aix-la-Chapelle	Kármán ...	Technical aerodynamics of flight... ...	2
	Polis	Meteorological science	1
Brunswick ...	Mosler ...	Wireless telegraphy	2
		Practical demonstrations in radio-telegraphy	3
	Schlink	Technical Mechanics III. (hydraulics, aerostatics and aerodynamics)	4
		Demonstration and repetition for the same	2
		Meteorology and aeronautics	1
Breslau ...	V. D. Born...	Theory of the aeroplane	2
		Demonstrations in aerohautics and meteorology	2
		Rudiments of meteorology	
Charlottenburg (1)	Becker ...	Airship and aeroplane engines	2
	Berndt ...	Electricity in the air	1
	Everling ...	Mechanics of free and captive balloons ...	1
	Dietziers ...	The construction and flying of an airship	1
	Kassner ...	The wind—its arising, measurement and application to the construction of tall buildings and harbours, navigation by sea or air as well as for the construction of wind engines	1
	V. Parseval...	Aircraft	2
	Romberg ...	Aero engines	2
		Sketches of internal combustion engines for ships and aero engines	4
	Schaffan ...	Experiments made with air and water propellers	1
Danzig ...	Föttinger ...	Selections from the physics of technical phenomena of currents	1
		Propellers for aeroplanes and hydroplanes	2
		Designing of propellers for aeroplanes and hydroplanes	2
	Rieppel ...	Engines for land, sea and aerial transport	2
		Demonstrations in the same	3
Darmstadt ...	Eberhardt ...	Airships in flight	2
		Science of flight	2
		Demonstrations in airscrews	6
		General lectures on flight	2
	Henneberg ...	Hydrodynamics	
	Schleiermaden	Aerodynamics in connection with flight ...	2
	Wirtz ...	Practical demonstration in radio-telegraphy	2

COLLEGE.	NAME OF LECTURER.	TITLE OF LECTURE.	NO. OF HOURS.
Dresden ...	Travelius ...	Introduction to meteorology	1
Hanover ...	Leithäuser ...	Electric waves and wireless telegraphy...	2
	Precht ...	Airships in flight	2
	Pröll	Aero-mechanics applied to engine-driven airships and aeroplanes	1
		Demonstrations in the same	1
Munich ...	Diekmann ...	Wireless telegraphy	2
		The electric and magnetic problems of flight	1
	Emden ...	Aerodynamics and the application of the same to the technical problems of flight	3
Stuttgart ...	A Baumann...	Aeroplanes and details of their construction	2
		Engines for land, sea and aerial transport	2
	Hermann ...	Wireless telegraphy	2
		Demonstrations in the same	4
	V. Koch ...	Meteorology (selections)	1
		Aerostatics and aerodynamics	2
Brünn ...	Szarvassi ...	Meteorology and science of climatic conditions	3
Graz	Wittenbauer...	Technical Mechanics II. (hydrostatics, hydraulics, mechanics of gases) ...	
		Airships and aeroplanes in flight ...	3
Prague ...	Pöschl ...	Hydromechanics (hydrostatics, hydrodynamics)	3
		Demonstrations in the same	1
	Spitaler ...	Meteorology and science of climatic conditions	3
		Practical demonstration of meteorology...	1
Vienna ...	Knoller ...	The airship in flight and the nature of engines	3
Zürich ...	Korda ...	Wireless telegraphy	1
	Wiesinger ...	Construction of engines (2)	3
		C. Agricultural Colleges.	
Berlin ...	Hess	Demonstrations in meteorology ...	1
		Practical meteorology and science of climatic conditions	1
		D. Commercial Colleges.	
Berlin ...	Mercuse ...	Geography, taking bearings on land, sea or in the air, with a demonstration at the astronomical observation station of the commercial college	1

(1) In addition Prof. Franke and Priv. Doz. Fassbender-Kock will give nine lectures, demonstrations and practical demonstrations in wireless telegraphy. See syllabus of lectures.

(2) Is a continuation of the lecture on Aircraft given in the Winter Session.

("Deutscher Luftfahrer Zeitschrift," May 22, 1918.)

ABRIDGMENTS OF RECENT PATENT SPECIFICATIONS (AERONAUTICS).

COMPILED BY MR. H. T. P. GEE, PATENT AGENT.

15,014. F. Sage and Co. and E. C. G. England, 58, Gray's Inn Road, London. October 23, 1915.

Planes, Arrangement and Disposition of.—Aeroplanes of the kind having staggered planes have the wing portions mounted so that they may be folded or turned back along the fuselage without being materially inclined to the longitudinal axis of the fuselage. The hinges of one of the planes are arranged in or on brackets projecting laterally from the wing girders so as to bring the axes of those hinges vertically in line with the corresponding axes of the other plane relatively to the longitudinal axis of the machine.

16,821. F. H. Page, 110, Cricklewood Lane, London. November 30, 1915.

Planes, Construction of; Cars.—To obtain easy access to portions of an aeroplane or the like, parts of the fabric are cut away and the edges of the fabric stitched around or secured to a rigid ring of predetermined size, the hole thus formed being normally covered by a detachable flap. The edges of the fabric are sewn around a metallic ring and the detachable flap is laced to a strip of canvas sewn on the fabric. This arrangement may be used on the main planes or on the fuselage.

121,479. A. Tebaldi, 79, Via Monte Rosa, Milan, Italy. December 10, 1918. Convention date, December 10, 1917. Not yet accepted. Abridged as open to inspection under Sect. 91 of the Act.

Tanks; Radiators.—In order to prevent leakage from a liquid storage vessel such as a petrol tank or a radiator when perforated by a bullet, the vessel has a vacuum maintained therein by means of an exhauster. To prevent ignition of the contents, the vessel is enclosed in an outer jacket, the space between the two vessels being filled with an inert gas such as the cooled exhaust from an internal combustion engine. A stream of exhaust gas is kept flowing through the tank by means of a small hole.

121,484. R. J. P. E. Cozette, 43, Rue Louis Blanc, Courbevoie, Seine, France. December 12, 1918. Convention date, December 12, 1917. Not yet accepted. Abridged as open to inspection under Sect. 91 of the Act.

Internal Combustion Engines; Carburetting.—In spray carburettors particularly for use with aeronautical engines, one or more nozzles situated in a chamber adjacent the float chamber deliver into conduits which communicate through holes with the outlet passages of the carburettor. The delivery from the nozzles is controlled by a ported extension of a manually actuated valve which admits air to dilute the mixture in the outlet pipes. The valve is held in place by a spider and is actuated by a lever. A second lever has in its boss an air hole and by adjusting this lever, the time at which air may be admitted through the tube to provide an altitude correction may be varied. The outlet pipes are jacketed. The float levers are positively connected to the float. The float chamber communicates through a hole with the chamber, excess fuel in which may be drained away.

121,495. A. A. Lemercier, 147, Avenue de Clichy, Paris. October 10, 1917.

Electrically Heated Clothing.—Clothing, especially gloves, caps, and boots for the use of aviators and motorists, is heated electrically. A plug terminal is connected to a source of current on an automobile, aeroplane, etc., and is provided with a flexible connection which, entering one of the pockets of a combination garment, passes between the outer fabric and the lining to a plate fixed to the garment between the shoulders. From this plate proceed wires which are attached to the lining by loops and terminate in plug couplings, which are enclosed in pockets at the neck, and at the ends of the arms and legs. A cap having ear flaps, gloves and boots are each provided with resistance wires and with a connection leading to a male portion of the plug coupling. Each plug socket is provided with a spiral spring, and the plug contact, which is mounted upon a flexible support, is formed as a snap fastener.

121,513. A. D. Thompson, Hill Crest, Merry Hill, Bushey, Hertfordshire. December 17, 1917.

Tanks.—Petrol and other tanks for aircraft, of the kind described in Specification 17,511/15, are provided with means for automatically rotating the cover when the tank is pierced, or with improved means for rotating the cover by hand. The automatic means comprises a plunger operated by a variation of pressure due to the entry of a projectile and controlling electric or mechanical means for rotating the cover through gearing. If the tank and cover are tapered, the cover is simultaneously moved longitudinally against the action of a spring by means of ratchet wheels on the cover and tank respectively. The cover may be longitudinally displaced and rotated by hand-operated means comprising a ratchet ring fixed to the cover, blocks carrying pawls and engaging spirally grooved members, and a loose ring fitted in a groove in the ring and connected to an operating lever. The packing between the tank and cover may consist of layers of felt or other soft material with an interposed layer of rubber.

121,657. R. H. Davis, 187, Westminster Bridge Road, Westminster. January 28, 1918.

Garments for Airmen.—To keep an airman warm, to sustain him should he fall into the sea, and to enable him to urinate, a garment is made of inner and outer impervious skins, the space thus formed being filled with hot air or the wearer's breath. Outside the outer skin is a layer of kapok or other buoyant material. Attached to a belt beneath the garment is a waterproof bag or receptacle, the lower end of which is provided with a non-return valve. A continuation of the bag forms a tube which passes to the outside of the dress and may end with a plug or cap.

121,661. J. E. Marshall, Caney, Kansas, U.S.A. January 31, 1918.

Inclinometers for Aircraft.—The instrument consists of a transparent sphere half filled with liquid, provided with graduations and encircled by a graduated plate, which is arranged at right angles to the plane of the graduations and is bolted to lugs projecting from the sphere.

121,741. J. W. Rapp, College Point, New York, U.S.A. (Assignees of J. Vanoris, Street, Brooklyn, New York, U.S.A.) December 19, 1918. Convention date, December 19, 1917. Not yet accepted. Abridged as open to inspection under Sect. 91 of the Act.

Planes, Construction of; Framework.—Ribs or spars of aerofoils are composed of upper and lower longitudinals each formed of metal plate bent into

T-section, the two longitudinals being connected together by diagonal braces having the ends bevelled and spot-welded between the inwardly-extending flanges of the longitudinals. The longitudinals are perforated.

121,813. H. W. Dover, Holyrood, St. James, Northampton. January 2, 1918.

Celluloid Panels; Windows; Aeroplane Coverings.—Celluloid and like sheets are provided on the margin with a strip of woven fabric doubled upon itself and cemented or solutioned to the two faces of the sheet, the invention being applicable to wind-screens and windows or look-outs for cars, ships, aircraft, buildings, and hoods of vehicles; and to mirrors, scale-marked covers for maps, and coverings for aeroplanes. The doubled portion may extend beyond the sheet and may form a tube which may have a core. The sheet may be clamped between inner and outer frames, or be secured by rivets between two frames. In one form a flat strip or core is inserted in the fold of the fabric, and the frame is formed as a split metal tube. The frame may comprise two wooden members secured together by screws which pass through the celluloid sheet. For covering an aeroplane wing, adjacent edges of the sheets overlap, and the fabric-covered margins are lapped over the nose of the wing to present a smooth leading edge.

121,838. R. G. Jakeman, 6, Kirkdale Road, Leytonstone, London. January 18, 1918.

Wearing Apparel.—A complete garment, a gas mask, or a garment to enclose a portion only of the body, suitable for use by airmen and others, is closed air-and-water-tight at the openings provided for putting on and taking off the article. One side of the opening of the rubber or like garment is provided with a double row of press-studs between which is an inflatable tube, while the other side of the opening is provided with a double row of sockets. After the fastenings have been engaged, the tube is inflated through a valve. In a modification, one side of the garment is provided with studs, arranged back to back, and with a soft rubber packing strip or a non-inflatable tube, while the other side has a double border each part of which carries a row of sockets. Gloves or boots may be connected to a main garment by similar means. Gas masks, which may be used alone, are provided with mica eye openings, and with a mouthpiece connected to a respirator associated if desired with an oxygen container; or an absorbent anti-poisonous pad may be provided. In some cases the mouthpieces or respirators and the members of the mask or headpiece designed to accommodate the ears may be made detachable.

121,968. J. W. Rapp, College Point, New York, U.S.A. (Assignees of J. Vanorio.) December 30, 1918. Convention date, December 28, 1917. Not yet accepted. Abridged as open to inspection under Sect. 91 of the Act.

Buildings, etc.—Frames or structures, such as are used in aeroplanes, are tensioned by members secured to the frame, etc., heated to elongate and telescope them, and then welded together while heated. In one form the member is heated and then welded to sleeves, which are secured to the frame and have slots to permit a secure weld. In a modification the member, secured at both ends to the frame, is heated and is melted at a point to allow a part to straighten, forming a bulging joint. The surplus metal at the joint is then removed.

121,980. S. Leech, 1, Westridge Road, Southampton. October 26, 1917.

Propelling.—A jet propeller for aircraft and vehicles comprises means for producing continuous high velocity jets of combustion products through conduits past a series of ejector vanes so as to produce a partial vacuum within the

apparatus and cause air to flow in from outside against deflecting vanes. The apparatus also comprises a receiving chamber, vapour chamber, a combined vapour engine and petrol pump, a vaporising coil, a vapour jet with a regulating valve, air induction vanes and combustion chamber.

121,990. J. G. Jackson, 525, Auburn Avenue, Buffalo, New York, U.S.A. December 7, 1917.

Aerial Machines without Aerostats; Planes, Construction and Arrangement of.—In aeroplanes of the kind provided with dihedral main planes and a tail portion comprising dihedral planes with a vertical fin underneath, the arrangement being such that the laterally projected areas of the dihedral surfaces equal the area of the fin, the dihedral and vertical tail planes are made of increasing width from front to rear, and the main planes are arranged at an angle of incidence slightly greater than that of the tail planes. The fuselage is fitted with dihedral main planes and tail planes and with a fin. One or more additional main planes may be provided.

BIBLIOGRAPHY.

Enclosed D.H. 4. Illus. ("Flight," Jan. 23, 1919.)

Pfalz Single-Seater Fighting Aeroplane. Illus. ("The Engineer," Jan. 31, 1919.)

America's Greatest Naval Flying Boat. Illus. One of the largest heavier-than-air craft in existence. ("Aeronautics," Feb. 5, 1919.)

Use of Aeroplanes for Forest Patrol Work. Outline of an American scheme. ("Aeronautics," Feb. 5, 1919.)

Civil Aerial Transport. Flying the Atlantic. G. Greenhill. ("Engineering," Feb. 7, 1919.)

Wireless in Air Navigation. Illus. ("Wireless World," Feb., 1919.)

Stress Optical Experiments. Illus. Major A. R. Low, R.A.F. ("Royal Aëronautical Journal," Nov., 1918.)

RECENT ADDITIONS TO THE LIBRARY.

"Technical Essays of an Aviator." W. R. D. Shaw. London, 1918: Economic Aircrafts, Ltd. Oct. pp. 64. 2s. 6d.

"A.B.C. of Aviation." Capt. Victor Pagé. New York, 1918: Norman W. Hemley Publishing Co. Oct. pp. 274. 10s. 6d.

"Standard Tables and Equations in Radio-Telegraphy." Bertram Hoyle. London, 1919: The Wireless Press. pp. 158, oct.

"Military Observation Balloons." E. J. Widmer. New York, 1918: The B. Van Nostrand Co. pp. 151, oct.

"The British Aircraft Industry." London, 1918: "The Times." pp. 305, oct.

"Decimal Coinage, Industrial Reconstruction and the Metric System." London, 1918: The Decimal Association.

"Electrical Ignition." M. A. Codd. London, 1918: E. and F. N. Spon. pp. 164, oct. 6s. 6d.

"Mathematical Recreations and Essays." W. W. R. Ball. London, 1918: Macmillan. pp. 504, oct.

"Aluminium." J. T. Pattison. London: E. and F. N. Spon. 1918. pp. 105, oct. 7s. 6d.

"Memoires du Géant." M. Babinet. Paris: E. Dentu. 1865.

"Company Training." R. C. B. Haking. London: H. Rees. 1915. pp. 473, oct. 6s.

"Erecting and Aligning Avro Biplanes." The Avro Co., Ltd., Manchester. 1918. pp. 58, oct.

"Recent Advances in Physical Science." P. G. Tait. London, 1876: Macmillan. pp. 362, oct.

"Revue Generale de l'Aeronautique." Libraire Aeronautique, Paris. pp. 95, oct.

"Manuel de Sciences Physiques, Manuel de la Locomotion et des Sports." Brussels, 1899: Institut International de Bibliographie.

"How to Prepare Saws." A. H. Smith. Rochdale, 1918: Robinson and Son. 33 pp., oct.

"Theory of Ballooning." Griffith Brewer. 8th Edition. 1918. The Royal Air Force.

"Medical and Surgical Aspects of Aviation." H. Graeme Anderson. London, 1919: Henry Frowde. pp. 255, oct. 12s. 6d.

"Italy's Part in the War." W. K. McClure. Florence: Bemporad. 1919. pp. 101, oct.

"Aircraft Identification Book." R. Borlase Mathews and C. T. Clarkson. London, 1919: Crosby, Lockwood and Co. Sm. oct., 118 pp.

"Expeditionary Force Canteens." Capt. E. Vredenburg. London, 1919: R. Tuck and Sons. Quarto, pp. 95.